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Emulsification rate of sheet-fed offset ink and its effect on printed quality

Qingyi Chen

EMULSIFICATION RATE OF SHEET-FED OFFSET INK AND ITS EFFECT ON PRINTED QUALITY

by

Ching-Yih Chen

A thesis summitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Printing in the College of Graphic Arts and Photography of the Rochester Institute of Technology

May, 1986

Thesis advisor: Mr. Chester J. Daniels

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Rochester, New York

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ABSTRACT

This thesis is a study of Surland's Emulsification Method, and is intended to demonstrate the effect of change in emulsification rate curve with different types of fountain solution whose surface tension was varied. The surface tension of a fountain solution can be changed by the addition of isopropyl alcohol. Two inks were modified to produce the same tack reading but a different emulsification capacity. Using the Surland method the two inks and two fountain solutions generate four different emulsification rate curves and these four curves are tested for their effect on printed quality.

The printing performance of an ink is judged by the ease with which an ink can obtain ink-water balance as well as the degree of freedom from printing problems such as "catching up" and plate scumming.

The printed sheets are sampled and the data is analyzed statistically using solid ink density and dot gain as response variables. The RIT Symmetrical Scale was included in the printing form design to facilitate solid ink density measurement and dot gain calculation. Solid ink density and dot gain variations are calculated within each printing run.

The addition of isopropul alcohol to a dampening solution not only reduces its surface tension and increase its wettability but it also suppresses an ink's continuous emulsification tendency. Ink and water balance is easily controlled when a printing ink is able to reach a state of equilibrim with dampening solution.

On the basis of observation during the on press printing run it was found that a high percentage of isopropyl alcohol in a dampening solution can dissolve the blue toner from the black ink and requires an increase of ink feed to obtain the desired optical density.

This study indicates the tendency of plate "catching up" can be associated with emulsification rate curves. The Pb type of emulsification rate curve can be so modified that press run will encounter fewer problems. Density variation within a press run is then more easily controlled.

Abstract approved: Chester J. Daniels, thesis advisor

Senior Technologist, title and department

May 30, 1986, date

CHAPTER I

INTRODUCTION

Sheet-fed offset lithographic presses are designed and manufactured with the assumption that press controls will be manipulated by skilled pressmen. The skill, experience and familarity of the operator with a particular press dictate his success of press adjustment resulting in successful control. The printing plates used on these presses consist of two distinct phases, an image area and a non-image area. The image area is treated to accept the ink and repel the water, while non-image area is treated to accept the water and repel the ink. In the actual printing operation the two phases established by the plate are difficult to maintain with a uniform result throughout a printing run because of the interaction of ink-water and surface properties established by the plate. This is partially due to the continuous contact of image surfaces with the dampening fountain roller and partially due to the ink and water interaction. Ink and fountain solution interaction also influence the normal functioning of the inking unit[1].

There are many factors that might directly or indirectly cause a change of printing process' working condition and these changes are not evident until the pressman inspects the printed sheets. The pressman always makes his judgement on the basis of the printed sheet and then makes the appropriate adjustments to the press.

The author believes that density variation on the printed sheet will be small if the process is stable. The process can be expected to be stable if pressman can select an optimum combination of ink and fountain solution prior to printing.

Statement of the Problem

A viable control technique to reduce color variation in printing short run four color jobs for sheet-fed offset lithographic presses is a very desirable goal. Color variation is thought of as a serious process flaw because the customer will quickly recognize the problem when he reviews the printed sheets. Process control is an important function of the pressman. Most press persons apply their skills to this end but sometimes they fail most likely because of the materials they are using.

Color variation is defined as the hue change among the printed sheets. Causes of color variation in printing in short run four-color printing with a sheet-fed offset lithographic press may be due to incorrect setting of ink feed and water feed, misregistration[2], the character of ink emulsification, ink and water interaction and imcompatibility with the type of ink and fountain solution selected. T. Lehtonen, researcher at the Technical Research Center of Finland studied the effect of ink feed on the variation in density of lithographic prints and concluded that in printing presses, most of the variation of solid ink density originates from variables that affect the amount of ink fed by the ducter roller[3]. Although ink trapping is considered a cause of color variation in four-color printing in wet on wet offset lithographic printing, it is usually considered neglegible in single color sheet-fed offset lithographic reproduction.

A test of the effect of each possible factor on the consistency of ink density on the printed sheet can give an idea of how each different variable functions on the press. The effect of each factor and the interaction between the factors to be tested shall be studied. Ink, fountain solution, paper and plate are considered as the sources or factors that cause the variation in the printed result. The response variables are expected to be solid ink density and dot gain.

A factorial experimental design is used for testing. It is powerful in many respects[4]:

1. The effect of several factors can be studied in the same experiment.
2. The effect of each factor at all levels of the other factors can be tested and discovered whether or not this effect change as the others change.
3. It allows testing not only for the effects of the factors separately-the main effects-but also to test for interactions-joint effects of two or more factors combined.
4. Every judgement was made about the effects of the factor is based on all the observations accumulated in the entire set of experiments, not merely on a few of the observations. Thus factorial experiments are more sensitive in the detection of small effects.

The set of combinations which cause the lowest ink density variation in the test printed sheets is considered the best one for that press under that particular working condition. It is considered the best set of combinations because it allows the press process to work with optimum stability.

The following is a summary of the factors to be concerned:

1. Ink: Inks used for sheet-fed offset lithographic printing are made to

accept some amount of water from the dampening fountain solution. An ink containing dispersed water must continue to distribute on the ink rollers and transfer well from blanket to paper. A good ink may contain between 10 and 20 per cent by volume of water without loss of working properties. Some inks have printed well with even larger volumes of water present and others break down as soon as 5 per cent water uptake is exceeded[5]. The rate of emulsification theory proposes that it is essential for the lithographic process that ink has some capacity to emulsify dampening solution into it's body[6]. Emulsification rate is thought to have an effect on ink transference. Ink containing dispersed water must vaporize it's water or be forced to vaporize water content in order to maintain its emulsifying capacity.

2. Fountain solution: Fountain solution is used to wet the non-image areas of the printing plate. The surface tension of a fountain solution is a measure of the strength of intermolecular forces. The surface tension of fountain solution can be determined by means of an instrument called the Du Nouy Tensiometer. Usually fountain solution surface tension ranges between 35 to 70 dynes/cm. The most popular method for lowering the surface tension of fountain solution is by addition of chemicals such as isopropanol, glycols or surfactants[7]. Fountain solutions with low surface tension tend to wet surfaces better than fountain solutions with high surface tension[8]. In press operation, pressman must maintain a water film such that complete coverage of non-image

areas is maintained. The printing process would be expected to be affected in its stability due to inefficiency of ink to emulsify fountain solution input from the dampening roller. Excessive surface water may cause a variation of ink transfer among the rollers.

3. Plate: A common type of scum found on grained metal plates is residual coating sum[9]. This kind of scum was caused by the coating that remains on the plate after development. The desensitized etch may keep the non-image areas clear of ink for several hundred prints and then the non-image areas of the plate would start to take inks. The term"etching" means desensitizing the non-image areas of the plate to ink. This is an important step in the platemaking process. Its purpose is to add a thin, invisible, but tightly adhering water-receptive gum film to the non-image areas. This film acts as a barrier to prevent ink from contacting and sticking to the plate metal. If the plate accidentally takes ink in the non-image area, the dampening solution causes the ink to be released and the plate clean up[10]. The plate which has an insufficient degree of desensitizing requires more fountain solution to keep the non-image areas clean.

Assumptions

Sheet-fed lithographic presses can produce more consistent ink density throughout the printing run if the process is maintained at a stable working condition. It is assumed that ink density variation among the printed sheets is due to process fluctuation in its inner mechanism.

Ink and water balance can not be maintained properly. Ink which has the capacity of being more forgiving to the presence of fountain solution should be able to keep the process in a stable working condition presumably resulting in lower ink density variation among the printed sheets. Fountain solution with various surface tension will contribute to printing process variation due to change in the amount of water feed required. Fountain solution may cause difficulty if the surface water can not be removed by the ink used for that printing.

FOOTNOTES FOR CHAPTER ONE

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CHAPTER II

REVIEW OF LITERATURE

In a recent work Aage Surland points out that lithographic ink efficiency can be affected by the ability of ink to emulsify fountain solution and the range of ink to balance with fountain solution[1]. His findings are new and are consistent with other authors who studied the effect of water on ink. In lithographic printing ink and water are continuously fed into the system via ink form rollers and the dampening system. Ink and water interact with each other and lead to emulsification.

There are two central mechanisms which lead to water in ink emulsification during lithographic printing[2].

1. The first mechanism occurs in the inker form rollers/plate nips in the image areas. A thin ink film left in the image areas in the plate/blanket nip is covered with fountain solution in the dampener/plate nips and comes in the nip against a thicker ink layers.

2. The second mechanism occurs in the inker form roller/drum nips in the non-image areas. The ink film on the ink form rollers pick up water from the surface of the well dampened non-image areas and comes against the ink film on the inker drum and its surface water. Because there is usually a significant amount of non-image area on the plate, this mechanism is very important.

Ink emulsification was furthur studied by Surland and he proposes characterizing inks by their rate of emulsification.

Emulsification

Oil and ink tend not to mix because there is a greater attration of water molecules for each other and of oil molecules for each other than between water molecules and oil molecules. If the ink is such that it has both a strong attraction for oil molecules and a strong attraction for water molecules, it will be capable of producing a colloidal solution. If the dispersing substance also has an attraction for oil molecules, and if an oil is contacted or mixed with the colloidal solution, the oil may be dispersed into small droplets and an oil-in-water type of emulsion can result (Figure 1). Each droplet has a surface film of the dispersing agent with the oleophilic group in the oil phase and the hydrophilic group in the water phase. On the other hand, if the effect of the oil-soluble portion of the molecule having mixed properties is sufficiently great, the substance can dissolve in water. The water-solubilizing group, however, has an attraction for water, and if the solution is contacted or mixed with water, the latter may be dispersed in the oil and produce a water-in-ink type of emulsion (Figure 2). These are two types of emulsification that exist in every lithographic press[3].

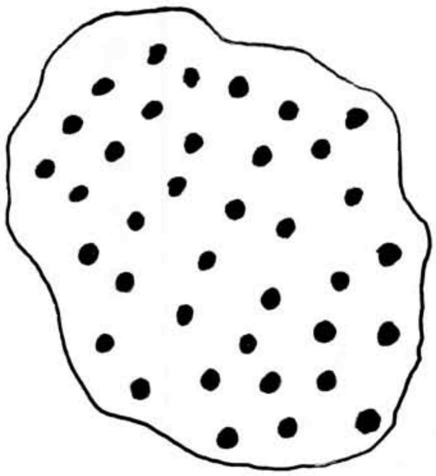


Figure 1: Ink-in-Water Emulsion

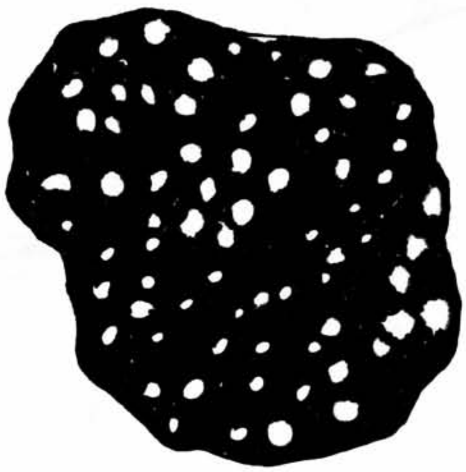


Figure 2: Water-in-Ink Emulsion

Inks are manufactured for the sheet-fed offset lithographic industry with various brand names by many different ink makers. Inks are different in their constituents and each individual ink has its own operating characteristic. Some inks might contain more emulsifying agents than other inks and these inks would be expected to have a greater tendency to emulsify.

Aage Surland developed a procedures to determine the rate of emulsification and then related this information to actual lithographic performance. He classified thousands of lithographic inks after laboratory tests into six curves i.e. Pa, Pb, Pc, Pd, Pe, Pf. These curves were plotted as the amount of weight of dampening solution emulsified by 100 grams of ink as a function of time in minutes. The Y axis, representing full miscibility between the two phases, (ink and dampening solution) and X axis representing absolute repellency between the phases. Figure 3 shows the six different possible emulsification rate curves[4].

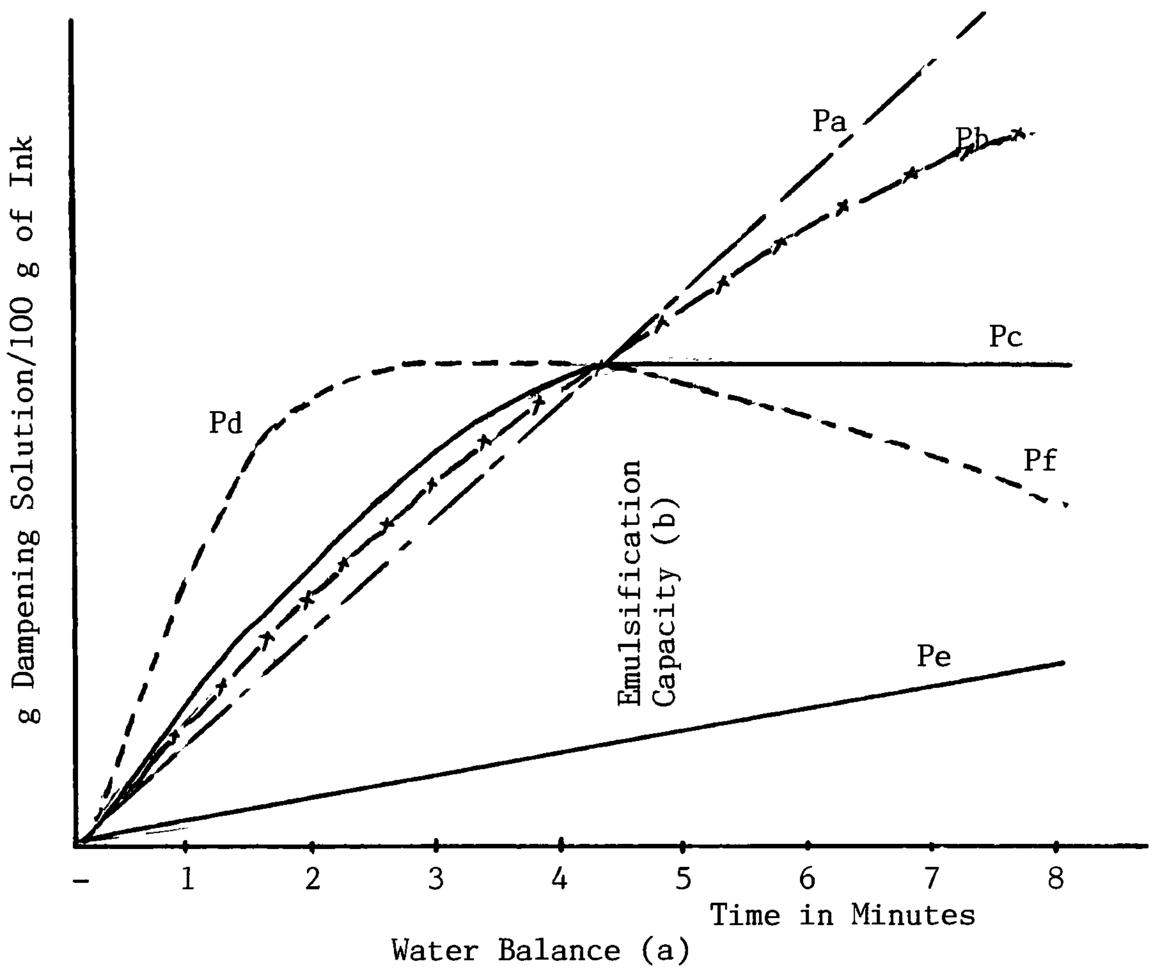


Figure 3: Surland's Emulsification Rates Versus Press Performance

The ink represented by curve Pa scums because it is miscible with water and both image and non-image areas of the plate accept ink. The ink represented by curve Pb shows rather narrow water balance and these inks are said to have a tendency for dot spread, mottled solids and low solid ink density in the printing. The narrow water balance requires that the feed of ink and dampening solution has to be readjusted frequently on the press. The inks represented by curve Pc exhibit wide water balance, are remarkably easy to run on the press and reproduce the plate image with a high degree of fidelity. The solid ink density is even. When the ink reaches its maximum rate of emulsification it tends to maintain a constant emulsification rate. The ink represented by curve Pd has very narrow water balance. When this ink reaches a maximum level of emulsification it reverses the emulsification process and increases water repellency to a point that the printed result shows a tendency toward dot sharpening. There also may be solids with high contrast mottling and low printed density. The ink represented by curve Pf can be a suffix to any types of the other curves. The ink ends up performing similarly to a Pd type of ink. The ink represented by curve Pe can not print images because this type of ink repels water strongly and transfer of ink to the image areas is prevented by the water film which is normally present over the ink form roller and plate image[5].

Rate of emulsification is a plot of the amount of weight of fountain solution emulsified by a given ink as a function of time in minutes. Brad E. Evans reviewed Surland's emulsification method and discovered ink of low water pick-up will emulsify more when in contact with a lower surface tension fountain solution while ink of high water pick-up will emulsify less fountain solution of lower surface tension[6]. Emulsification rate of ink is affected by the fountain solution selected. In order to select a proper fountain solution it is desirable to use Surland's emulsification method to analyse the effectiveness of the ink to emulsify the fountain solution.

Effect of Fountain Solution on Performance

Fountain solution is used to wet the non-image areas of the plate and prevent the non-image areas from taking ink from ink form rollers. All fountain solutions are very dilute solutions of chemicals such as calcium floride, chromic sulfate, chrome alum, tannic acid, glycerin, nickel salts, etc. Fountain solution which has a high surface tension may have more difficulty to wet the non-image areas completely than fountain solution which has a low surface tension. Fountain solution with a lower surface tension may tend to wet the images of the plate possibly causing problems with ink transfer and image sharpening. Wetting agents can be used to lower the surface tension of the fountain solution and these can affect the emulsification capacity of the ink. Surland studied and evaluated the effects of the fountain solution on the rate of emulsification. He concludes that the significant variation of ink performance with the different fountain solutions, shows that the selection of dampening solution is of great importance for the efficiency of the printing process[7]. Inks perform well when the fountain solution has a surface tension of about 40 dynes/cm. The ink has poor performance when the fountain solution is about 65-70 dynes/cm.

In sheet fed lithographic printing it is important to select the proper fountain solution for the ink to be used. Improper selecttion of fountain solution can result in poor ink performance and cause troubles for the pressman. Inappropriate selection of materials may require pressman to spend an inordinate amount of time to control ink and water balance. For color printing each process ink might as well need a different fountain solution if better performance is to be achieved. This might be very important because Surland's performance gradings of fountain solutions shows that a set of four colors ink using the same type of fountain solution do not have the same gradings on their performance.

Lithographic Plates

It is very important that the platemaker make a good plate for the pressman. A good plate is more forgiving to broad changes in ink and fountain solution characteristics thus the pressman can print acceptably with greater ease. If the plate is not made well then it becomes difficult for the pressman to maintain ink and water balance. Excessive fountain solution feed may be required in order to keep the plate clean with a trade off for transfer problems due to excess of surface water. This situation can become worse if the ink used has a narrow range of water balance. In a production situation, plates are often not well processed due to negligence or other reasons causing erratic response on the press. One solution to the problem can be the selection of an ink with a wide range of water balance that reducing the need for constant press adjustment and thereby reducing waste on time and materials.

To maintain consistent printed ink density throughout the run limited variation in the process is required for each commerial job. To maintain quality the pressman must carefully observe the printed sheets, then make adjustments as necessary to ink feed or water feed in order to minimize variation in printed ink density.

There are coarse, medium, fine and grainless plates. Finer graining allows the use of a finer screen and it is expected that better formed dots will be printed. Less water used in the process might be expected to reduce problems of the effect of water in ink and obtain constant ink transfer[8].

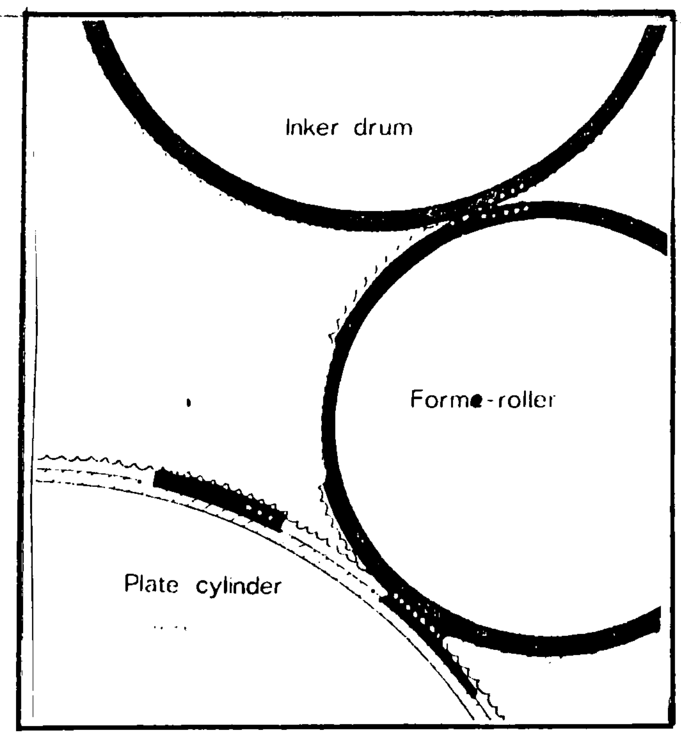
Choosing the proper fountain solution for a given ink and choosing an ink with a wide range of water balance may reduce difficulties with plates with both medium or fine grain. Inappropriate combinations of ink and fountain solution can increase printing problems when the printing plate was not well made.

Effect of Surface Water

In each printing cycle the image area is wet by the fountain form roller. Figure 4 illustrates the water film transferred to the image areas by the fountain form roller as well as non-image areas[9].

Figure 4:

Water Film Transferred to Image Areas by Fountain Form Rollers as Well As Non-Image Areas



The effect of surface water is dependent on the capacity of an ink to emulsify water. If the printing ink being used has very poor emulsification capacity then surface water can inhibit ink transfer because the ink transfer is based on ink film splitting[9]. Increase in ink feed will not improve ink transfer but might cause scumming[10]. Preliminary studies of the effect of surface water on the ink tack readings indicates that its presence will reduce the ink tack readings on the inkometer. Various inks produce different responses due to the same amount of surface water added to inkometer rollers. Some inks produce only a minute change in the tack readings when water is added. Figure 5 shows ink tack readings change with respond to the addition of same amount of surface water in different sheet-fed offset inks.

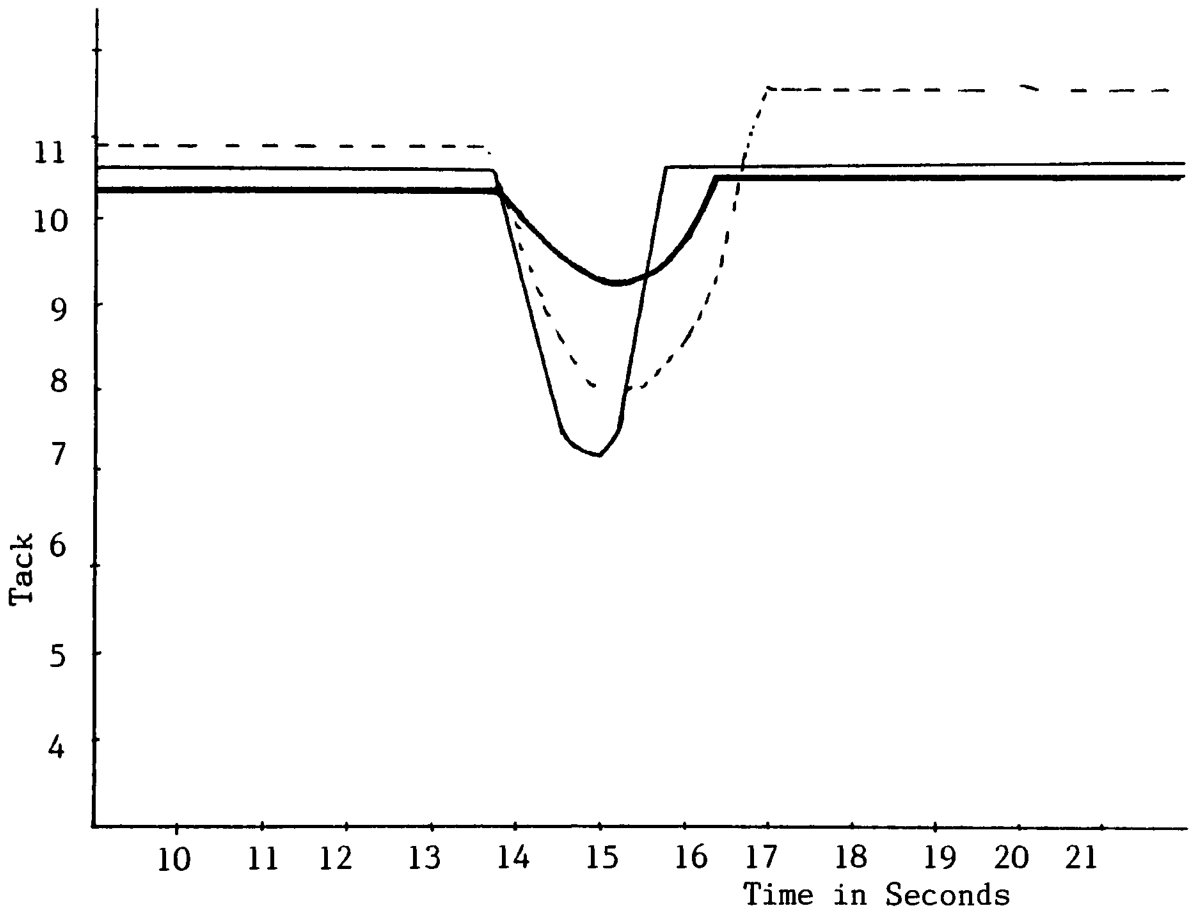


Figure 5: Ink Response Due to Addition of Surface Water in the Tack Reading

This preliminary study indicates that different types of lithographic sheet-fed offset inks have different response toward the added fountain solution. An ink with poor emulsifying capacity can be seriously affected by the existence of surface water film in its ability to transfer. The time needed for the drop in ink tack on the inkometer to return to the original tack reading seems to be related to the surface tension of the fountain solution but furthur investigation is required.

Optical Density Loss Versus Water Gain

T.A. Fadner and F.J. Doyle studied 6 types of lithographic news ink for water pick-up[11]. The result of their experiment indicates that some inks required lower dampening setting to print scum free while other inks required a higher dampening setting. The inks which required higher dampening setting often print with a lower optical density. If the ink has a lower emulsification capacity a greater ink density variation is found. The ink which required a lower dampening setting can run with higher optical density but the printed density variation is still related to its emulsification capacity. The test ink with the lowest printed density variation is the ink with an emulsification rate curve similar to that pointed out by Surland as an ideal ink. This ink has about 129% of water pick-up rate and water balance at 6 minutes.

All the test inks are shown to have a tendency to decrease in ink density after the second and the third recycled printing run but the degree of decrease is dependent on the type of ink used. The ink that requires the higher dampening setting in order to run scum free should have adequate emulsifying capacity or the result will be large variation among the printed sheets. The density variation is caused mainly by the existence of surface water on the test ink which produced the greatest printed optical density change. This type of ink is similar to the ink which has an emulsification curve shown by Surland as Pe type.

It is very possible that printed density variation among the printed sheets can be reduced by a choice of ink anf fountain solution such that the ink will transfer properly without being disturbed by the surface water. The printing process can continue functioning stably. With the appropriate choice of materials the printing process can proceed most smoothly. Improper ink and fountain solution combinations can cause the process to fluctuate and result in undesirable variation.

Ink and Water Balance

Ink and water balance is defined as the amount of ink and water delivered to the plate to produce the correct contrast[12]. Figure 6 is a simplified illustration representing the meaning of ink and water balance.

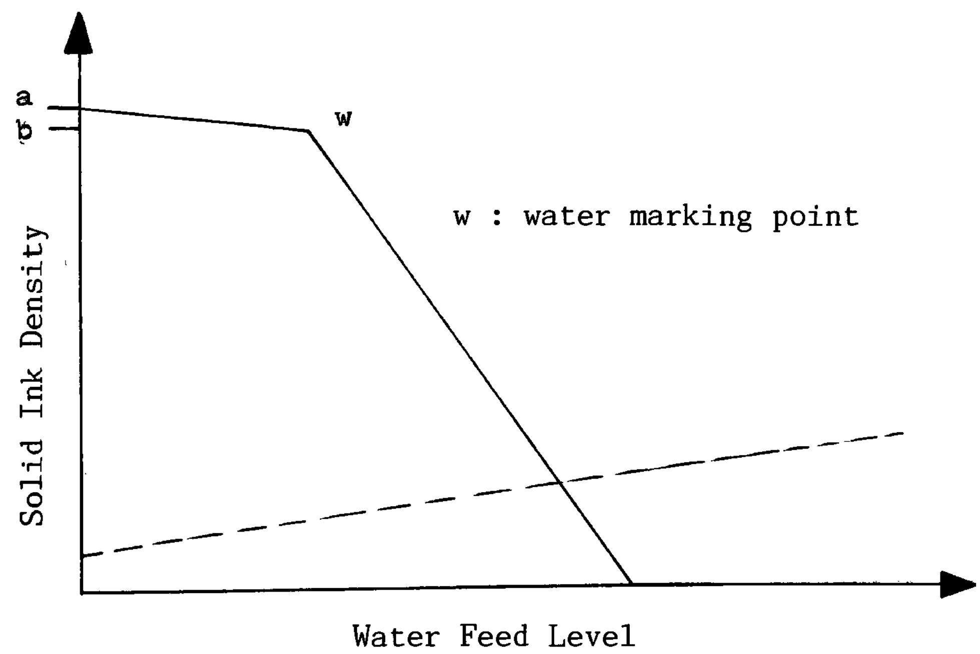


Figure 6: Solid Ink Density Change As a Function of Water Feed Level

The pressman has some limited leeway in printed density by increasing or decreasing the ink film thickness. This is shown in Figure 6 as the optical density range ab. Surland defined ink and water balance as the water feed at which printing is obtained free of scumming and water marking[13]. The ink which has a wide range of water balance is one that prints well after scumming and can continue to print well with more water feed. Zero water balance is an ink that can not produce an acceptable print with any combination of water and ink feed. In general it can be expected that most inks have a very small water balance area; improper control can lead to fill-in or scumming.

In the printing operation there are a number of factors that alter the ink and water balance, notably[14].

1. The amount of water delivered to the plate.
2. The amount of gum used in the water
3. The water resistence of the ink.
4. The quality of the image in relation to ink receptability.
5. The amount of water emulsified in the ink at a given instant.

A suitable lithographic sheet-fed offset ink according to Surland's suggestion should have wide water balance capacity as well as adequate emulsification capacity.

FOOTNOTES FOR CHAPTER TWO

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CHAPTER III

HYPOTHESES

Research Question

Does Surland's method of classifying ink quality also predict the variability of solid ink density and dot gain ?

Hypothesis

The working hypothesis for this study is summarized by the following:

If a simulated printing production run is conducted using both an ideal ink (Pc type) and a non-ideal ink (Pb type) then the ideal ink is expected to produce a lower variability in solid ink density and dot gain.

The size of variation is determined two standard deviation and the values may be compared directly.

We will reject the statement that the printing using a Pc type of inks will produce a smaller variation of solid ink density and/or dot gain if the sample sheets collected from one of the two printing runs using the ideal inks has a variation equal to or greater than either of the printing runs using the non-ideal inks.

CHAPTER IV

METHODOLOGY

Experimental Design

In order to investigate if the ideal inks always produce lower variation in solid ink density and dot gain than the non-ideal inks when printing with a sheet-fed lithographic printing press, the following are required: two lithographic printing plates (3M Tartan 60 Negative Subtractive Working Plate); two types of emulsifying characteristic of the same ink (one ink was modified by changing its emulsification capacity); two fountain solutions (at two levels of surface tension, high and low). There are four different emulsification rate curves are produced. A test printing form is prepared for the four printing runs and each of them is expected to require three thousand sheets. An advanced pressman will operate the printing press. A skilled operator is expected to minimize the press variables and it is the author's hope to use the new T & E Center Heidelberg two color sheet-fed offset press to perform the four printing runs. The response variables of this experiment are solid ink density and dot gain. The RIT Symmetrical Scale is used for both measurements. The sampling procedure is the same for each run. Random sampling on the printed sheets is adopted and there are fifty samples collected from each run. Table 1 shows the design of the simulated production runs.

Table 1 : Design of A four Simulated Production Printing Run

	Modified Ink (+ glycerol)	Normal Ink (no glycerol)
Alcohol Dampening Solution (low surface tension)	Ideal Ink (Pc Type)	Ideal Ink (Pc Type)
Non-Alcohol Dampening Solution (high surface tension)	Non-Ideal Ink (Pb Type)	Non-Ideal Ink (Pb Type)

Test of Emulsification Rate

The testing procedure is based on Surland's standard procedure and the major errors in the emulsification rate test are prevented by some extra precautions:

Mixer

The adapted equipment for the standard procedure uses a Sunbeam " Mixmaster " modified for the test. A flat bottom mixing bowl is placed on a larger diameter freely-revolving turntable and two opposite driven mixing blades (90 rpm) each contact the bottom of the bowl over their widest width and conform to the bend of the bowl to its vertical side. Properly aligned, the bowl during the test slides from side to side on the turntable, allowing the mixing blades to scrape ink off the sides of the bowl. The center distance of the mixing blade is 42mm.

Prestirring of the Ink

The ink prior to the test is brought to a state of agitation similar to that in which it is on the rollers of a printing press.

Addition of the Fountain Solution

The standard procedure, recommends the addition of fountain solution in increments of 15 ml from a 100 ml reservoir prior to each mixing period.

Mixing Speed

The standard procedure for the test uses 90 rpm mixing speed.

Separation of Free Solution

The way to separate the surplus free solution is done carefully in order to avoid error. No stirring is allowed to separate the surplus water from the ink. Using only one minute to do the separation process as recommended by Surland.

Testing Temperature

The temperature is 73 F $\pm$ 2 F. recommended in the standard test procedure.

Relative Humidity

Relative humidity is 50% $\pm$ 5%.

Gravimetric Versus Volumetric Determination

A loss of dampening solution during the test due to transfer, splatter and evaporation is in the range of 2.5 to 6 grams. The loss is independent of the maximal emulsification. The emulsification is determined as weight gain of the ink phase therefore gravimetric determination is used.

Preparation of Fountain Solution

Tensiometer

Tensiometers are used in the measurement of small force i.e.

surface tension of a liquid or interfacial tension between one liquid and the other liquid. The one which is available is cat. nos 70545 tensiometer manufactured by Central Scientific Company. The instrument should be calibrated so that the dial reading is the apparent surface tension expressed in dynes/cm. If a known weight M is placed on the ring and balanced by the torsion in the wire, then the dial reading P is given by the following equation:

$$P = \frac{Mg}{2L}$$

Where

M= weight expressed in grams

g= gravity in cm/sec^2

L= mean circumference of ring in centimeters

P= dial reading = apparent surface tension in dynes/cm

Calibration

The standard calibration procedure has to be followed in order to obtain meaningful readings about the liquid's surface tension:

1. Clamp the tensiometer torsion arm with the adjustable stops
2. Hang the dry platinum ring on the hook
3. Cut and fit a small strip of paper on the ring as a platform
4. Release the torsion arm
5. Turn the knurled knob until the index and its mirror image are exactly in line with the reference line on the mirror
6. Loosen the dial clamp and rotate the dial until the vernier indicates approximately zero
7. Tighten the dial clamp and rotate the fine adjustment knob until the reading of the vernier is exactly zero
8. Place known weight of 600 mgs on the paper platform

9. Turn the knob until index is opposite the reference line on the mirror
10. Adjust the length of torsion arm if the dial reading does not match with the calculated value.

Preparation

Imperial Mark III Fountain Solution is the one selected fountain solution to be mixed with isopropanol to produce the desired surface tension. Isopropyl alcohol is used mainly to reduce the surface tension of a diluted fountain solution. Five fountain solution are prepared for the preliminary emulsification rate test and their surface tension are 35, 40, 50, 60, 70 dynes/cm respectively. The prepared fountain solutions are only different in their surface tension values and their contents are kept as close as possible. Table 2 indicates the different mixture volume of diluted fountain solution, isopropyl alcohol and distilled water to produce an equal value of five different surface tensions

Table 2: Per Cent Mixture of Diluted Fountain Solution, Isopropyl Alcohol and Distilled Water and the Produced Surface Tension

No.	Diluted F.S.	Isopropyl Alco.	Distilled H_2O	Surface Tension
1	60	0	40	72.0
2	60	10	30	43.1
3	60	20	20	32.3
4	60	30	10	27.0
5	60	40	0	25.0

The surface tension of each fountain solution is measured using the tensiometer. The solution is placed in a clean container such as an evaporating dish, watch glass or beaker about 4.5 cm in diameter and the container then is placed on the sample table. With screw in its uppermost position raise the entire table assembly until the ring is immersed approximately 5 mm in the test solution. Lower the entire assembly until the ring is just above the surface of the solution and centered with respect to the container.

Increase the torsion of the wire by rotating the knob and at the same time lower the sample table by means of screw so as to keep the index on zero. Continue the same operation until the film breaks.

The scale reading at that breaking point of the film is the apparent surface tension P.

A plot of surface tension versus per cent isopropyl alcohol may now be generated. By connecting the five data points a curve is formed and this curve may be used to find the correct mixture of diluted fountain solution, isopropyl alcohol and distilled water by interpolation.

Each of the five different fountain solution are prepared and will be used in the test of emulsification rate as well as in the test of the effect of surface water on the tack reading.

pH of the five solutions is adjusted with 2N hydrochloric acid or phosphoric acid to the same pH value. The common pH value is 3.5 which is acidic. This common pH value is used because it has the greatest buffering capacity[1].

Effect of Surface Water on the Tack Reading

Setup

Thwing-Albert inkometer, Thwing-Albert direct reading attachment and Hewlett Packard X-Y recorder are basic instruments for the testing and recording of the effect of surface water on the tack readings. Figure

7 is the setup.

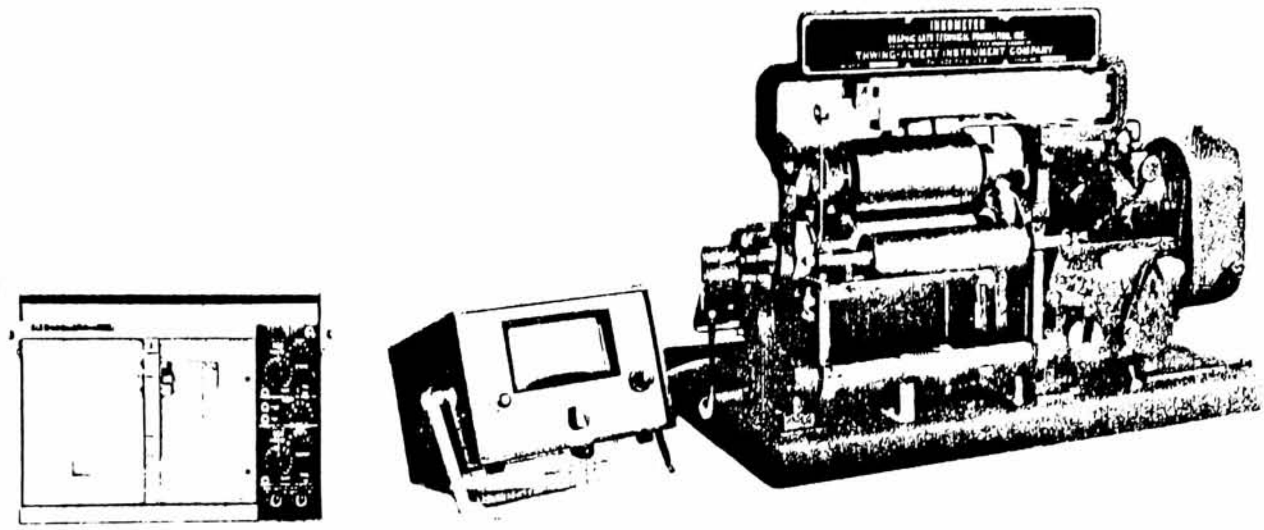

Figure 7: Layout of Inkometer, Direct Reading Attachment and X-Y Recorder

Inkometer

An inkometer is an instrument designed to measure the tac of lithographic and printing inks under conditions in which the degree of working of the ink closely approximates that taking place during printing. The results are the numerical values for the torque required to "work" the ink film at a known rate, with predetermined film thickness and temperature. Records can be either in tack readings or curves of time vs tack. Temperature is set at 90 degree Fahrenheit which is recommended to be the most satisfactory for general ink testing purposes. The ink to be tested is taken out from the ink can and put into a volumetric container called an ink metering device. Excessive ink is scraped away with a spatula to ensure a constant volume of ink metered out. This ink is then transferred to the inkometer rollers. To avoid excessive flying of the ink when the inkometer is started, the initial distribution is done by turning the motor coupling by hand. Start the inkometer and timer whenever it is ready.

Direct Reading Attachment

Inkometer tack reading can be read from this meter connected to the inkometer. By using this meter the dynamic tack reading can be observed and the readings can also be recorded by including an X-Y recorder.

X-Y Recorder

The basic function of An X-Y recorder is to produce a graphic tracing showing the relationship between two variables or one variable against time. For this experiment the Y coordinate will be tack reading and X coordinate will be time. With the graph paper the time interval can be calculated by measuring the length of the X axis which is calibrated in time. The model 7030A Series is equipped with a time sweep generator for use on both X and Y axes. Because the equipment is to record tack reading versus time the range selector is set to X axis and the sweep speeds are tested to find the proper one for the particular experiment such that the generated data can be interpreted easily. Operation on the most sensitive range may result in excessive noise. This electrical noise may be generated near by instruments or machines. A 10 K or smaller resistor at the input terminal may be required to correct this problem.

Sample Volume

The amount of each type of fountain solution for each test is maintained as closely as possible by following standard operating procedures when fountain solution is put into the front rubber roller of the inkometer using a micropipette (10ml to 250 ml). The desired amount of fountain solution for the test in order to manifest a significant level of surface water effect on the tack reading changes due to different ink emulsification capacity is determined by trial and error.

Standard Operation Procedures

1. Check the temperature. 90 F is the temperature for all the test.
2. Shift to high running speed.
3. Zero both Direct Reading Attachment and X-Y recorder.
4. Switch to Time Sweep Operation and set the sweep rate switch at the desired speed.
5. Fill the ink metering device or volumetric container with the ink to be tested, by means of a spatula. The ink must not be taken from surface layer of the ink in the can.
6. Evenly distribute the ink across the front rubber roller of the inkometer. Turn the motor coupling by hand to make initial distribution before starting the inkometer, timer and X-Y recorder.
7. Start inkometer, timer, Direct Reading Attachment and X-Y recorder.
8. Inject the desired volume of fountain solution to the nip of rubber rollers very carefully with the pipette held perpendicular to the roller. Injection of fountain solution is performed 20 seconds after starting the instrument.
9. Allow to run 40 seconds then stop.

Plate Making and Press Run

Plate

Two printing plates are used for all the four test runs. The plates used are 3 M Tartan 60 Negative Subtractive Working Plate. The same test form which is 11" x 17" is used. One plate is made with the test form on its right hand side while the other is made with the same test form on its left hand side. Two plates are exposed and processed equally that these two plates have approximately the same printing characteristic.

Selected Inks and Fountain Solution

After the test of emulsification rate of several inks by using Surland's method, one ink is selected for the press performance test. The ink is ranked as an ideal printing ink when it is used with a fountain solution which has its surface tension at 30 dynes/cm. The ink becomes a non-ideal ink when it is used with a fountain solution which has its surface tension at 72 dynes/cm.

The other printing ink for the press performance test is obtained by modifying that selected ink. The ink is mixed with glycerol and it becomes more water repellent when it is used with the fountain solution which has surface tension about 30 dynes/cm. Both of these two test inks have the same initial tack reading.

Two fountain solutions are selected for this experiment. They have their surface tension of 30 and 72 dynes/cm respectively. The two fountain solution are the ones which are expected to have the greatest effect on the ink's emulsification capacity.

Paper

The same batch of coated paper is used for all the printing runs and the paper is Westvaco Celesta Litho Gloss Sub 100 paper.

Press

The printing press for the test run is a new Heidelberg offset two color sheet-fed printing press. This press is equipped with electronic press and quality control system CPC and Alcolor continuous dampening unit. A device called Royse Alco-Miser is used to maintain constant alcohol content throughout the run. A blower is positioned between the inking rollers to increase the evaporation rate of the emulsified ink so that the ink can maintain a constant emulsification capacity.

Operator

A highly skilled pressman is used to operate the printing press and he is capable of maintaining good control over the problems encountered. The operator operates the press according to a set of standard operation procedures.

It is assumed that experimental error associates with operator will be insignificant. It is also assumed that experimental error due to the press is not significant.

Standard Operation Procedure

Normal press operation procedures are used for each level of this experiment but the following are some of the notes for the operator:

1. Take approximately the same amount of printing ink from each individual ink can and put it to the ink fountain pan for each printing station.
2. Replace the fountain solution with the one for that particular test. Use Royse Alco-Miser Circulation system to maintain a constant alcohol content.
3. Adjust ink feed and water feed to produce 1.4 solid ink density on the printed sheets without scumming or water marking.
4. Complete makeready and start the printing run
5. Control of printed sheets visually to maintain constant printed quality throughout the run.
6. Make necessary adjustments if the printed quality start to deteriorate or the printing plate starts to scum.

7. Record the adjustment.
8. Finish the printing run, washup and repeat step 1 through 7 for another set of printing run.

The printing plate is divided into two sides i.e. the image side and the non-image side. Figure 8 shows the layout.

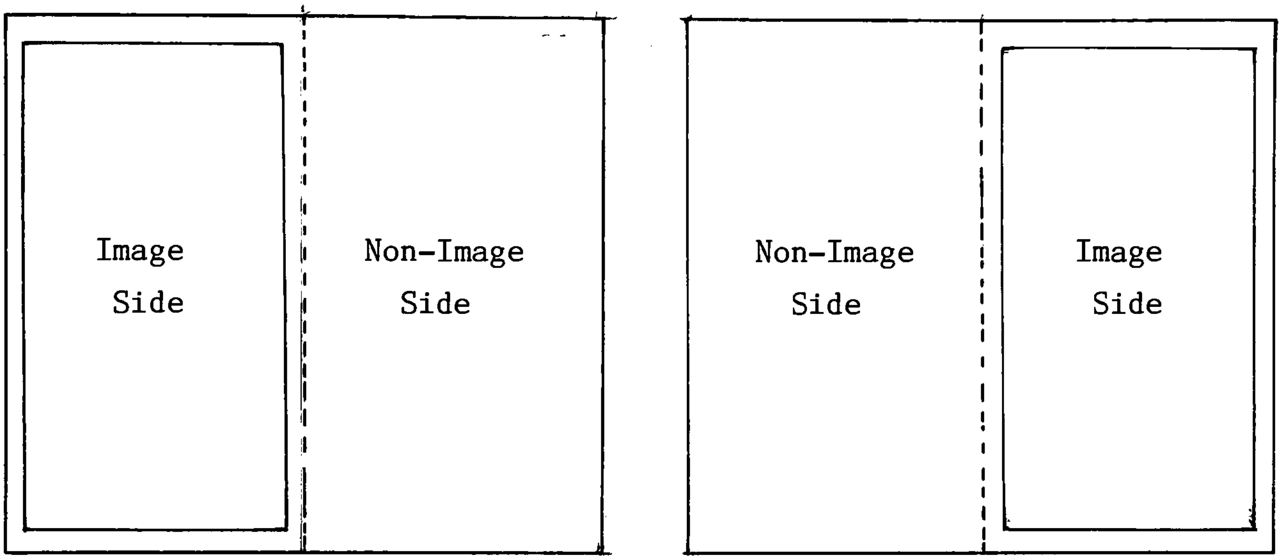

Figure 8: Layout of Two Printing Plates Used in Printing Press Runs

The test form is shown in Figure 9. It includes screen tints of two different ruling, RIT Symmetrical Scale. The photographs are included in order to assist the pressman to judge his settings based on subjective response.

150 LINE	5	10	20	30	40	50	60	70	80	90
133 LINE	5	10	20	30	40	50	60	70	80	90

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150 LINE	5	10	20	30	40	50	60	70	80	90
133 LINE	5	10	20	30	40	50	60	70	80	90

GRAPHIC ARTS TECHNICAL FOUNDATION

FOOTNOTES FOR CHAPTER FOUR

1. Surland, Aage, "A Laboratory Test Method for Prediction of Lithographic Ink Performance," TAGA Proc. 1980, p. 222-247.

CHAPTER V

RESULTS

Introduction

With regard to the experimental work performed, this thesis includes the following three critical experiments:

1. A review of Surland's emulsification rate method including a differentiation of the character of selected printing inks according to the resulting emulsification rate curves.
2. A test of the effect of surface water on tack readings by use of a bench inkometer.
3. A printing press trial intended to find the relationship of printed quality with emulsification rate curves.

Surland's emulsification rate test method was modified because of the limits of the available Sunbeam "mixmaster" on blade speed and torque. The recommended method was attempted but could not be maintained because the viscosity of the test inks stalled the motor at the recommended blade speed rate (90 rpm). The blade speed of the modified method is increased to 320 rpm which produces a torque sufficient to provide uniform mixing of the ink with the fountain solution. The mixing time is reduced to 0.28 minutes which is equivalent to the Surland recommended mixing requirement of 90 strokes of the mixing blade.

The mixing procedures are changed somewhat in order to match the modified method. The standard operating procedure used is outlined by the following:

1. Pre-stir 50 grams of the test ink for 0.1 minutes.
2. Charge the mixing bowl containing the ink with 15 ml of fountain solution.
3. Start mixing, rotate the bowl counterclockwise slowly and allow the blades to scrape ink off the side of the bowl, avoid splashing.
4. Decant the supernatant water, wipe out splashed water drops remaining inside or outside the mixing bowl.
5. Never stir the emulsified ink to remove any additional water.
6. Weigh the bowl along with the blade, calculate the gained weight of each mixing operation.
7. Repeat steps 2 to 6 at least eight times for each test.

Eight sheet-fed offset inks tested for emulsification rate are listed in alphabetical order at table 3:

Table 3 : Ink Data of Eight Sheet-Fed Offset Inks for Emulsification Rate Test

Ink Manufacturer	Brand Name and Ink Color	Manufacture Date
Braden Sutphin	PMS sparkle set spanish yellow	08/16/85'
Capico	PMS base process blue	11/28/83'
Capico	PMS base rubine red	11/10/83'
Capico	PMS base process blue	11/28/83'
Capico	Speedmatch radiant pantone base blue	
Marathon	Hard dry premium ten black	01/16/86'
Sinclair & Valentine	Sinvalith yellow	01/30/85'
Superior	Offset speedway process black	

Emulsification Rate Test Results

Table 4 lists the emulsification rate curves of the above eight selected sheet-fed inks using Surland's emulsification rate test method. Each test response is the weight in grams of fountain solution emulsified by 100 grams of test ink after each mixing operation. There are eight data points for each test ink and each test fountain solution.

Table 4 : Emulsification Rate test Results

Ink Type	Fountain Solution	1	2	3	4	5	6	7	8
#1	0	15.0	22.2	31.2	37.6	44.2	51.0	57.6	63.6
#1	235	11.8	18.8	25.8	30.6	36.4	40.6	43.0	43.8
#2	0	15.0	22.8	30.8	38.2	45.0	53.4	58.0	64.6
#2	235	11.6	19.0	24.2	27.6	34.4	38.4	40.0	41.8
#4	0	25.4	30.4	37.0	43.2	46.4	48.8	55.2	59.8
#4	235	11.8	19.8	26.0	33.8	40.8	43.6	47.6	50.6
#6	0	14.4	22.0	28.0	34.0	39.2	43.4	46.0	50.0
#6	235	15.6	24.4	28.2	31.6	31.8	31.8	32.2	32.2
#7	0	13.6	21.6	30.2	36.4	42.0	48.6	53.0	59.6
#7	235	13.8	17.4	25.0	30.6	33.9	37.2	37.2	37.4
#8	0	16.2	22.8	28.0	33.2	39.8	43.2	47.6	50.8
#8	235	15.4	22.4	26.8	32.4	33.4	33.4	35.6	36.0
#9	0	13.6	22.2	30.0	39.8	49.6	60.8	74.0	82.6
#9	235	12.0	17.4	25.6	29.0	36.4	42.8	47.4	55.2
#10	0	14.0	22.6	29.6	36.6	42.0	47.2	55.0	57.8
#10	235	15.2	23.2	28.4	33.8	36.6	37.8	39.4	41.0

Each ink was mixed with two types fountain solution, the FS-0 and FS-235. Fountain solution FS-0 contains no added isopropyl alcohol and FS-235 is mixed with 23.5% isopropyl alcohol by volume. Figure 10 is a graphic representation of emulsification rate of the eight inks and

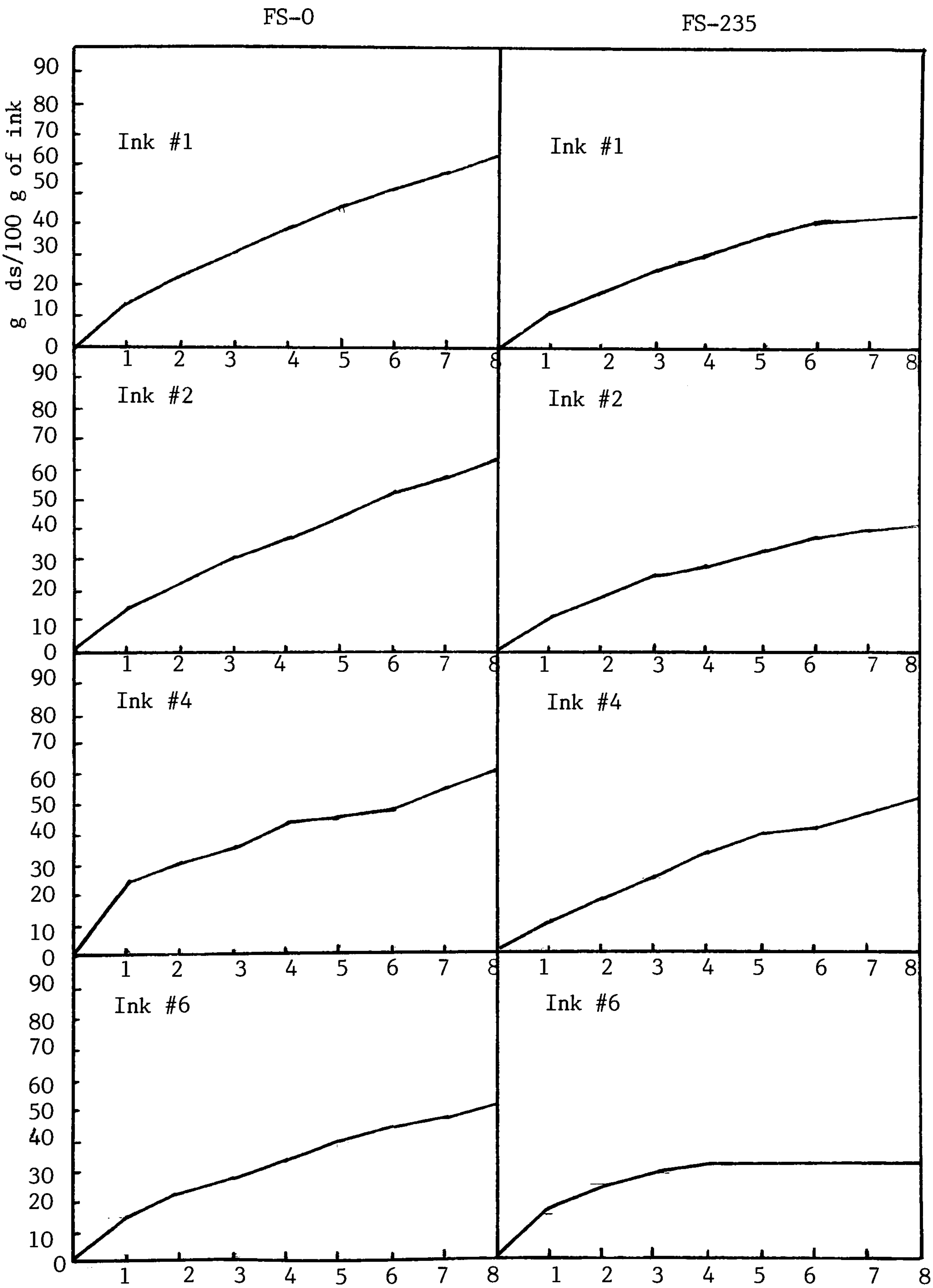


Figure 10 : Graphic Representation of Table 4

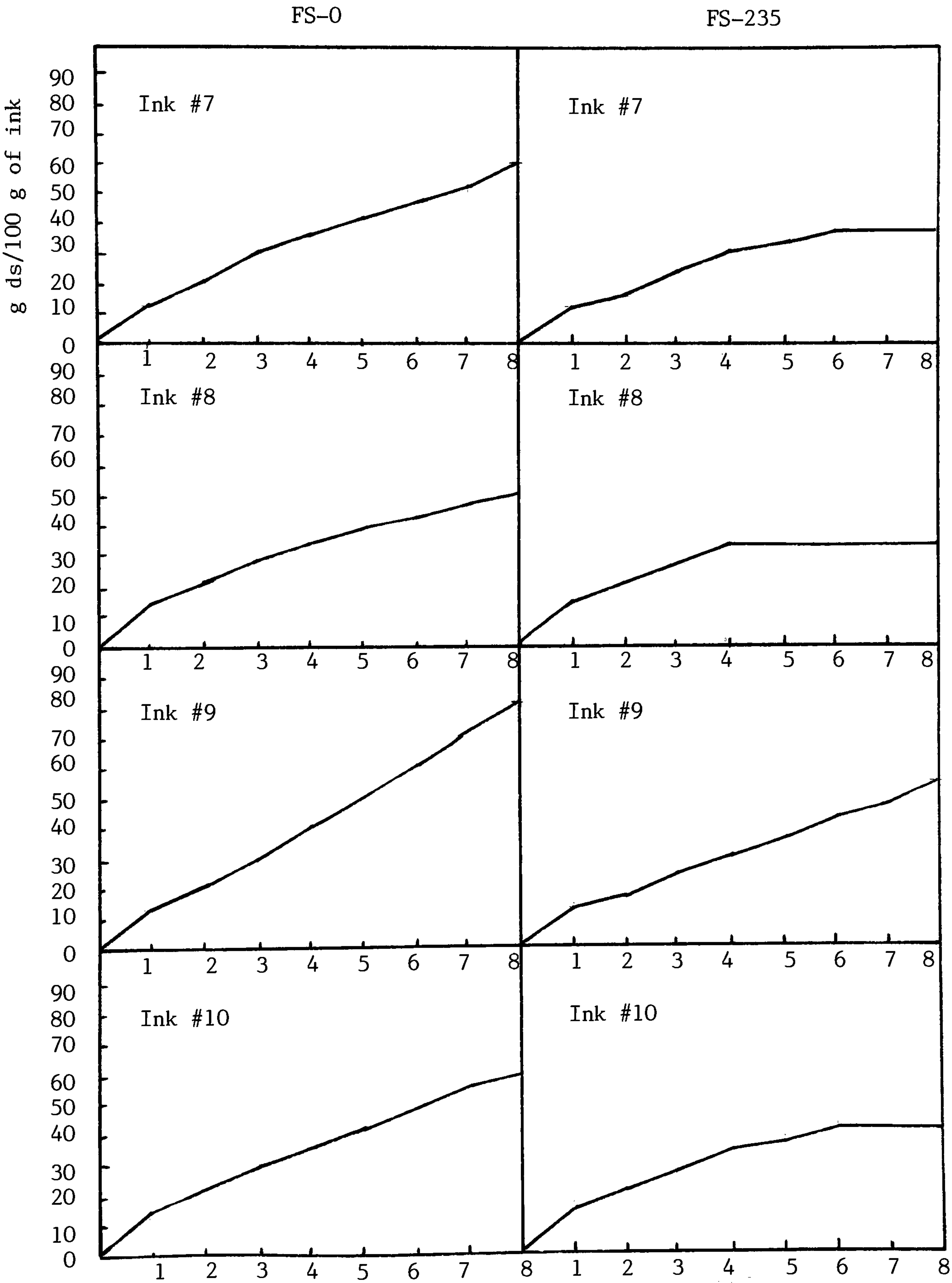


Figure 10 : Graphic Representation of Table 4 (continued)

two fountain solutions. An interesting note is that all the curves are changed by the presence of alcohol in the fountain solution. This observation agrees with Surland's conclusion with regard to the effect of fountain solution surface tension on emulsification rate curves.

According to Surland's classification of lithographic printing inks, the emulsification rate curves of inks 6, 7, 8 and 10 may be said to be ideal inks when used in combination with fountain solution FS-235. These inks are not classified as ideal when used with fountain solution FS-0.

A repeatability experiment is designed to test this method. Inks #6, 7, 8 and 10 are chosen to perform the test. The test results are shown in table 5 and a graphic representation of the results is shown in Figure 11. The solid line is the first measurement and the dotted line is the second measurement.

Table 5 : Repeatability Test of Four Selected Inks

Ink Type	Fountain Solution	1	2	3	4	5	6	7	8
#6	0	14.8	21.0	26.6	31.8	36.4	41.0	43.4	48.4
#6	0	14.0	22.4	27.2	33.0	38.2	42.4	46.0	49.6
#6	235	15.2	23.0	28.4	31.2	31.4	32.4	32.4	32.4
#6	235	13.8	23.0	28.6	30.4	31.8	32.2	32.4	32.2
#7	0	13.4	21.8	30.6	36.0	42.8	48.0	52.0	56.6
#7	0	14.0	21.8	29.8	36.2	42.0	48.4	53.8	60.6
#7	235	14.4	18.4	25.2	30.2	34.4	37.4	37.6	37.4
#7	235	13.0	15.2	25.2	31.0	34.2	37.2	38.2	38.6
#8	0	14.2	23.6	30.2	32.6	40.0	44.4	49.4	51.8
#8	0	15.0	24.8	30.6	34.4	41.0	44.4	49.0	51.4
#8	235	12.2	18.2	24.2	28.8	29.8	32.6	32.6	32.2
#8	235	13.6	21.2	27.6	31.4	33.2	33.8	33.4	33.8
#10	0	13.4	21.0	28.8	35.4	42.8	50.0	56.2	59.4
#10	0	15.0	24.6	30.8	37.8	44.6	48.8	54.8	61.8
#10	235	12.2	21.0	28.4	34.8	38.0	39.4	39.4	39.8
#10	235	14.2	23.6	30.6	36.6	39.4	40.2	40.4	40.2

There is variation between each replicate, The variation indicated is tolerable and the main concern of this experiment is to demonstrate the possibility of obtaining approximately the same curves. The curve shapes are critical.

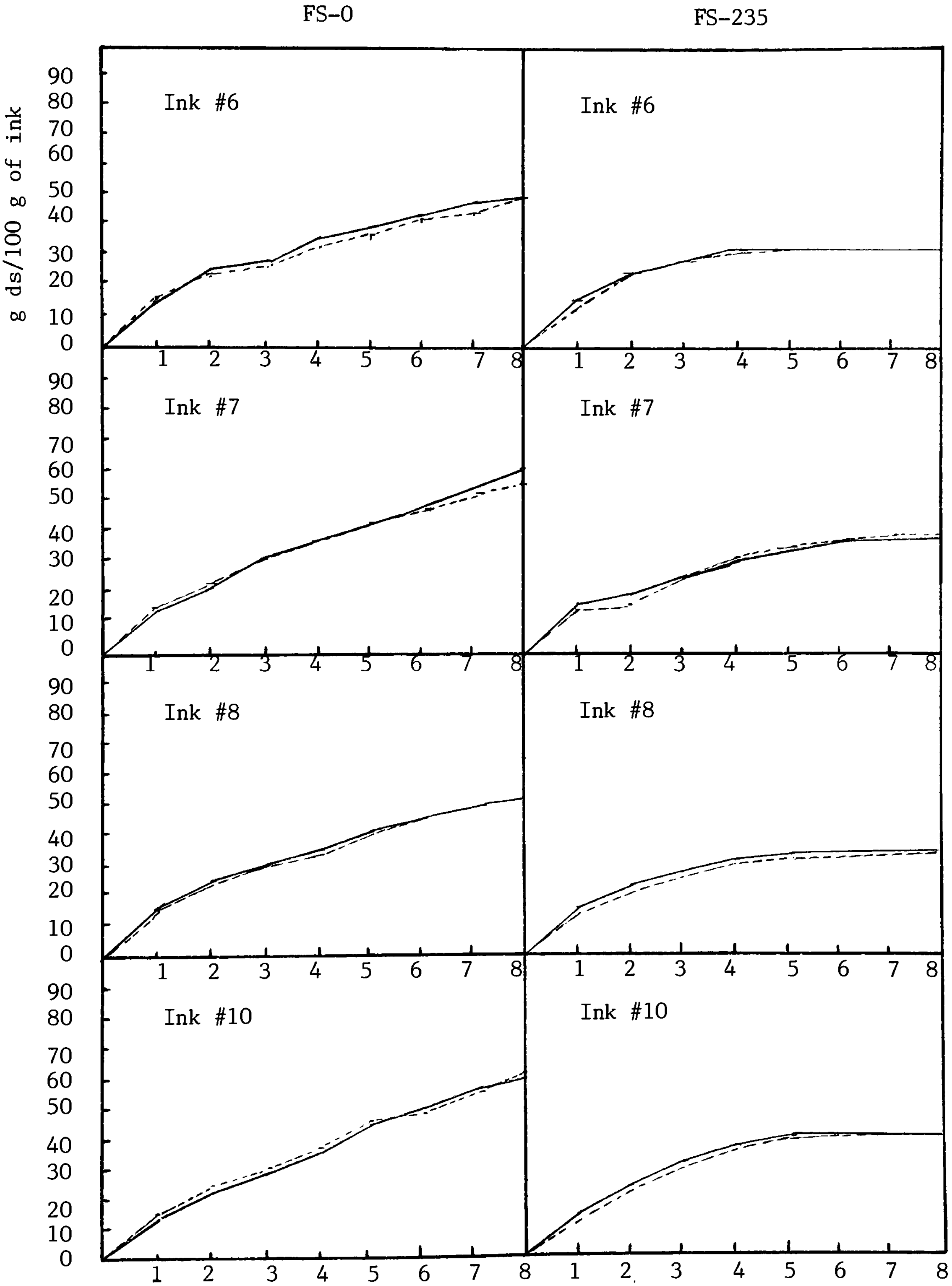


Figure 11 : Graphic Representation of Table 5

The prediction of an ink's printing performance based solely on the emulsification rate curve is the main purpose of this study. In order to avoid the introduction of other factors into this experiment the preparation of inks for the printing run is well examined. Ink type #6 is chosen because it has the following attributes:

1. It is a black ink allowing the pressman to see the results of printing. This allows maximum ability for visual control of printing variation.
2. It is a high tack ink. The inkometer tack reading of this ink is 16.0 at one minute, 1200 rpm.
3. It is miscible with glycerol and the mixed ink maintains the same ink tack after the glycerol is added.
4. It is immediately available.

Ink type #6 is mixed with 10% glycerol by weight to produce a second ink type and this ink is designated as ink type #6-M. These inks become different in terms of emulsification capacity but have the same ink tack as measured by the inkometer. Figure 12 and 13 shows the recorded inkometer tack readings of the two inks. The effect of tack therefore is excluded from this experiment.

Ink #6 and #6-M are mixed with two different fountain solutions respectively producing 4 different emulsification rate curves. The fountain solutions used are FS-0 and FS-235. Curve I-1 and I-2 are classified as the ideal inks and they are the two inks mixed with dampening solution containing alcohol. Curve II-1 and II-2 are the two inks mixed with non-alcohol dampening solution and they are classified as non-ideal inks. The classification is based upon Surland's method.

Figure 14 shows the four different emulsification rate curves formed by ink #6 and ink #6-M with two fountain solutions.

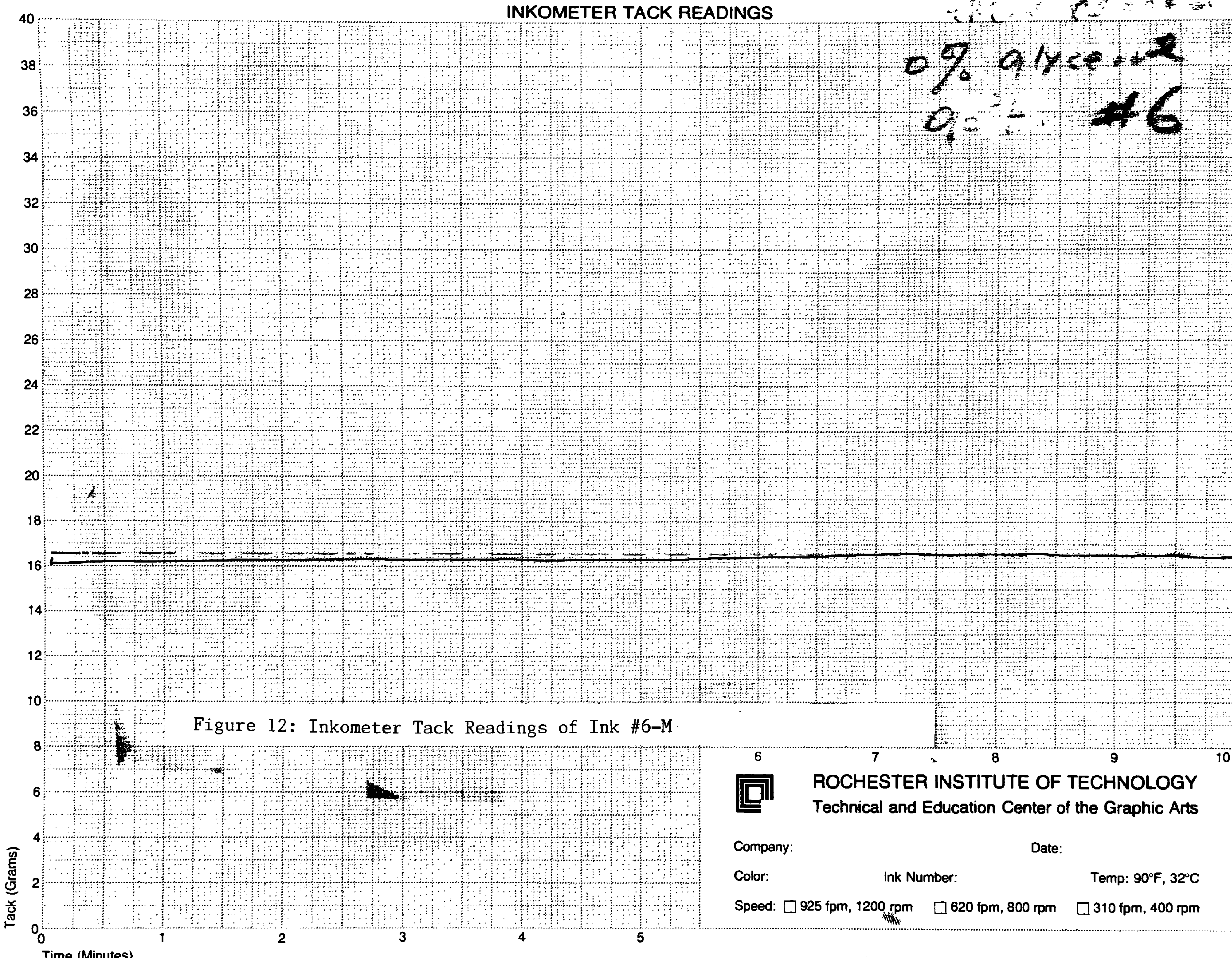


Figure 12: Inkometer Tack Readings of Ink #6-M

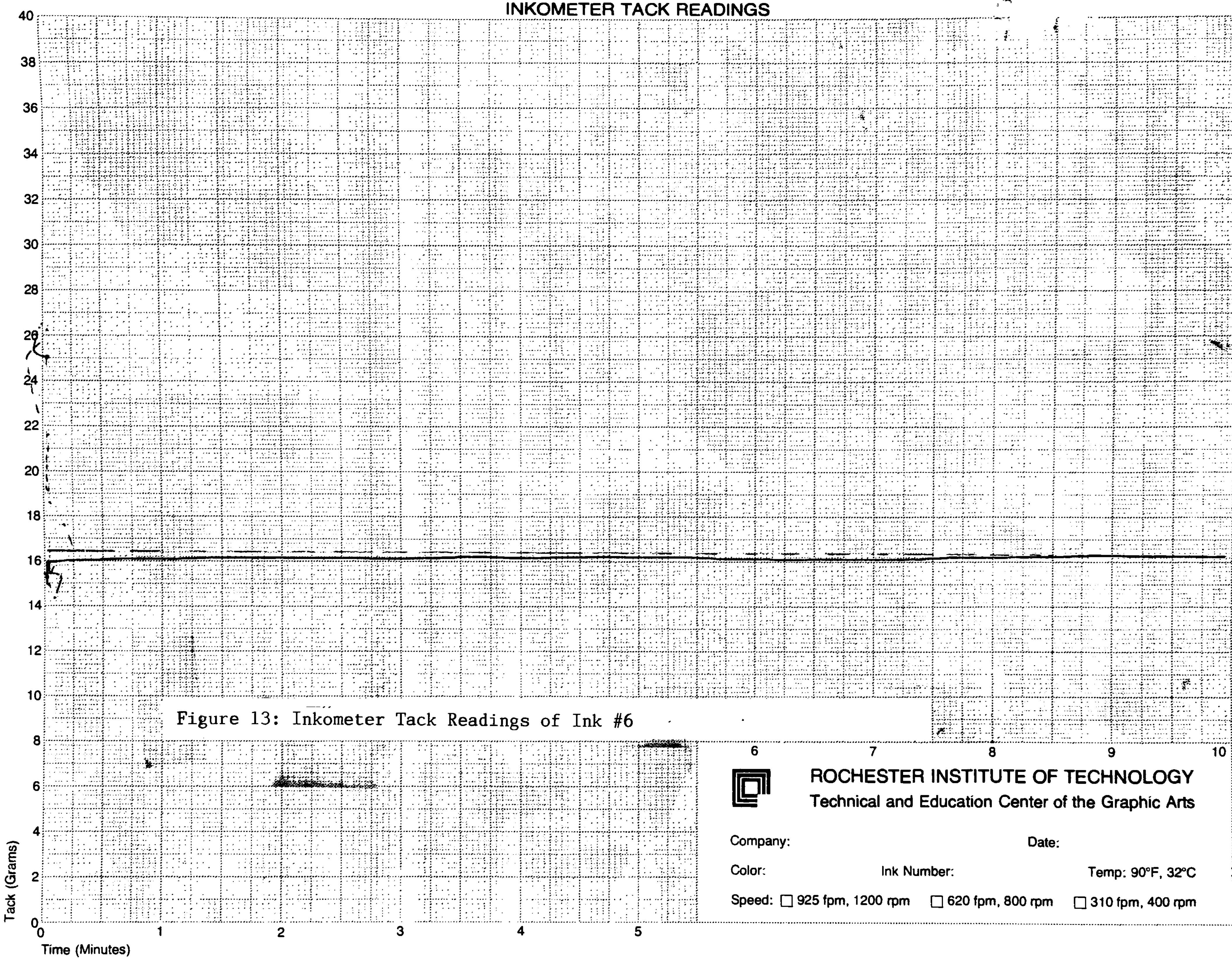


Figure 13: Inkometer Tack Readings of Ink #6

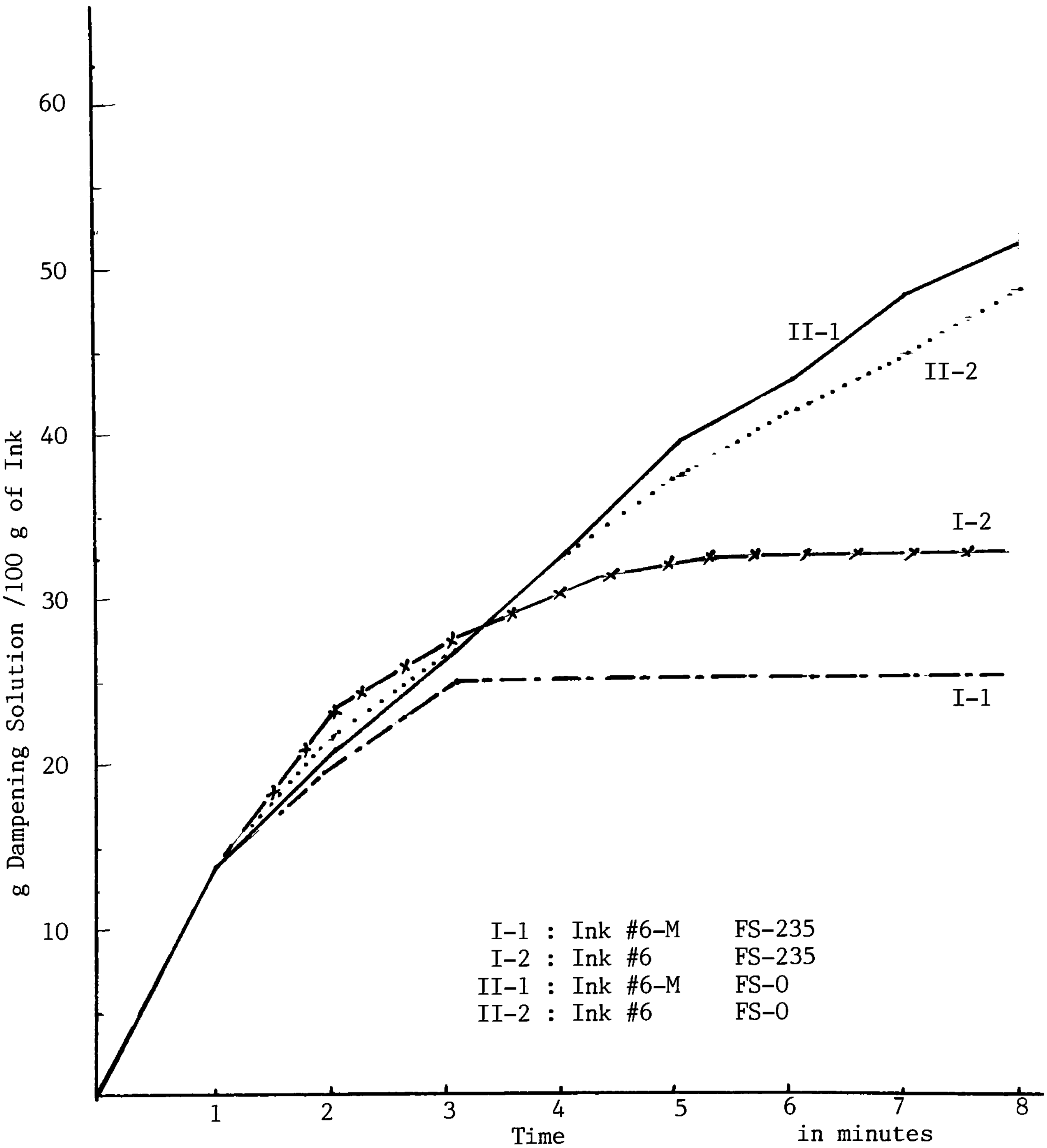


Figure 14 : Emulsification Rate Curves of Two Inks Under Two Types of Fountain Solution.

Per Cent Addition of Isopropyl Alcohol and the Surface Tension

The diluted fountain solution is mixed with various percentages of isopropyl alcohol as described in chapter III. The plot of surface tension versus per cent isopropyl alcohol is shown by figure 15.

Figure 15: Surface Tension Versus Per Cent Alcohol

Figure 15 shows the greatest marginal decrease in surface tension at about 16-17% of isopropyl alcohol. Figure 15 also allows determination of the required percentage isopropyl alcohol to make up a fountain solution which has surface tension of 30 dynes/cm. The indicated alcohol amount is 23.5%. The diluted fountain solution without alcohol has a surface tension about 72 dynes/cm at 20° C.

Effect of Surface Water on Tack Readings

10 sheet-fed offset inks were tested for tack drop due to the addition of surface fountain solution using a bench inkometer following the procedures described in chapter IV. The data were registered by an X-Y recorder in graphic form and the resulting tack drops were calculated. Table 6 is a listing of the tack drop data of the 10 selected inks. Each ink was tested with four different volumes of fountain solution. The tack drop is a measurement of the amount of tack difference between two tack readings. The initial tack reading before the addition of surface water is measured followed by a second reading which is the lowest tack reading after the addition of fountain solution.

Table 6 : Tack Drop Data of 10 Selected Sheet-Fed Offset Inks in Various Volume of Surface Water

F.S. Volume \ Initial Tack	15.6	15.8	15.2	12.3	16.0	16.8	13.2	14.8	19.8	16.0
40 (ml)	0.9	1.0	0.6	0.6	1.0	0.9	0.8	0.9	1.4	1.2
80	2.0	2.0	2.0	1.6	2.2	2.2	1.6	1.8	2.8	2.5
120	3.0	2.9	3.1	2.3	3.2	3.2	2.3	2.9	4.6	3.5
160	4.1	4.1	4.1	3.0	4.0	4.3	2.8	3.9	5.8	4.5

The data show in table 6 indicate that the amount of tack drop has direct relationship with the added volume of water and the initial tack reading. Inks which have higher initial ink tack have a greater tack reduction than those inks which have lower initial ink tack.

Comparison of Surland's Method with Inkometer Method

With Surland's method the emulsification tendency of an ink is determined by the shape of emulsification rate curve. The method used in producing the curves is very simple but the curve is capable of showing the dynamic changes of ink's miscibility with fountain solution at each mixing state. The proposed inkometer method does not supply the same type of curve as Surland's method.

Since the printing ink is subject to dynamic change in the inkometer, the Surland method is not replaceable with the proposed inkometer method.

Printing Press Experiment

Introduction

Makeready was carefully performed before starting the simulated printing production run for this test. The inks were put into each respective ink fountain of each printing unit with approximately the same quantity. The overall ink feed as well as individual ink keys were adjusted at control panel to produce the solid ink density of 1.6 across the printed sheet. After adjustment the ink keys were kept the same for each of the printing runs but it was found necessary to change the overall ink feed for the second printing run. The overall ink feed for each station was recorded numerically. The dampening system were adjusted to just above plate scumming and the fountain solution feed data was obtained from the scale reading at each printing unit. The printing speed is 6,000 impressions per hour for each printing run.

Observation During the On Press Experiment

The printing run was started with the alcohol dampening system.

The fountain solution feed was set to 4.5 at both printing units. The overall ink feed is displayed and set at the press control panel by pushing the station select button. Printing unit one was finally set at an overall ink feed reading of 88, while setting of printing unit two was 70. The production run continued smoothly without any disruption. Printing run I was terminated at about 3,000 impressions.

After wash-up the new inks and new fountain solution with no alcohol were applied to the press. Fountain solution with alcohol was found contaminated with dye stuff of the ink. It is possible that the toner of the printing ink was dissolved by the alcohol. The press run was started with no change in ink or fountain solution feed settings. The plate scummed when the press was started. Fountain solution feed was increased to produce scum free prints. The fountain solution feed was increased to 5.5 (previous setting was 4.5) at printing unit one and 7.0 for printing unit two. Ink feed had to be reduced to 68 (from 88) for printing unit one and 46 (from 70) for printing unit two in order to maintain the targeted solid ink density of 1.60. Printing unit one required adjustment to fountain feed three times during the 3,000 impressions run in order to avoid scumming and the fountain feed was finally adjusted to 6.7. Printing unit two was adjusted once to avoid scumming and the fountain solution feed reading is above 7.0.

Results

The printed sheets were sampled randomly but at interval of approximately 50 impressions. 50 samples were collected from each run and the data is obtained by measurement of the RIT Symmetrical Scale. The printed solid ink density and the density of 50% dot area were included in these measurements. Table 7a, 7b, 7c, 7d, 9a, 9b, 9c, 9d are lists of data collected from two printing runs and two printing units.

Table 7a : Solid Ink Density Data of 50 samples Collected From Press Run I-1 (Alc FS; Ink + 10% Glycerol)

1.44	1.45	1.46	1.46	1.47	1.46	1.46	1.47	1.45	1.48	1.45
1.45	1.47	1.46	1.43	1.46	1.44	1.41	1.45	1.46	1.42	1.47
1.44	1.45	1.44	1.43	1.44	1.42	1.43	1.45	1.44	1.44	1.43
1.45	1.44	1.45	1.43	1.46	1.44	1.45	1.44	1.42	1.44	1.41
1.42	1.39	1.43	1.35	1.39	1.42					

$\bar{X}$ = 1.44 S= 0.025

Table 8a : Frequency Distribution of Table 7a

Cell Boundaries	Midpoint	Tally	Frequency
1.335 - 1.355	1.345	*	1
1.355 - 1.375	1.365		
1.375 - 1.395	1.385	**	2
1.395 - 1.415	1.405	**	2
1.415 - 1.435	1.425	***********	11
1.435 - 1.455	1.445	*********************	21
1.455 - 1.475	1.465	************	12
1.475 - 1.495	1.485	*	1
			Total =50

Table 9a : Ink Density of 50% Dot Area of 50 Samples Collected From Press Run I-1

0.52	0.50	0.52	0.52	0.51	0.51	0.49	0.49	0.50	0.51	0.51
0.51	0.51	0.52	0.53	0.52	0.52	0.50	0.52	0.51	0.51	0.54
0.53	0.53	0.52	0.52	0.52	0.52	0.51	0.51	0.54	0.51	0.53
0.52	0.52	0.54	0.52	0.55	0.53	0.55	0.52	0.51	0.52	0.51
0.51	0.52	0.51	0.50	0.52	0.52					

$\bar{X}$ = 0.52 S = 0.013

Table 7b : Solid Ink Density Data of 50 Samples Collected From Press Run I-2 (Alc FS; Normal Ink)

1.38	1.35	1.39	1.37	1.37	1.34	1.37	1.38	1.37	1.39	1.37
1.34	1.38	1.37	1.36	1.36	1.37	1.35	1.33	1.36	1.35	1.36
1.35	1.33	1.35	1.39	1.34	1.33	1.35	1.34	1.33	1.32	1.35
1.34	1.34	1.36	1.35	1.33	1.37	1.36	1.34	1.35	1.34	1.36
1.36	1.35	1.32	1.39	1.39	1.40	$\bar{X}$ = 1.36 S = 0.020				

Table 8b : Frequency Distribution of Table 7b

Cell Boundaries	Midpoint	Tally	Frequency
1.315 - 1.335	1.325	*******	7
1.335 - 1.355	1.345	******************	18
1.355 - 1.375	1.365	****************	16
1.375 - 1.395	1.385	********	8
1.395 - 1.415	1.405	*	1
			Total =50

Table 9b : Ink Density of 50% Dot Area of 50 Samples Collected From Press Run I-2

0.50	0.49	0.51	0.50	0.49	0.49	0.49	0.50	0.49	0.50	0.49
0.49	0.49	0.49	0.51	0.49	0.50	0.50	0.50	0.50	0.50	0.50
0.50	0.50	0.50	0.50	0.50	0.49	0.50	0.50	0.49	0.49	0.51
0.51	0.50	0.50	0.51	0.50	0.52	0.52	0.51	0.51	0.52	0.52
0.52	0.53	0.52	0.52	0.53	0.52	$\bar{X}$ = 0.50 S = 0.012				

Table 7c : Solid Ink Density Data of 50 Samples Collected From Press Run II-1 (FS No Alc; Ink + 10% Glycerol)

1.32	1.38*	1.38	1.38	1.35	1.34	1.35	1.32	1.33	1.32	1.35
1.35	1.40*	1.40*	1.37*	1.40*	1.41*	1.43*	1.43	1.38*	1.37*	1.34
1.34	1.33	1.33	1.31	1.33	1.34	1.35	1.34	1.32	1.35	1.35
1.35	1.36	1.37	1.36	1.37	1.36	1.37	1.36	1.37	1.38	1.37
1.37	1.36*	1.37	1.38	1.36	1.36	$\bar{X}$ = 1.36	S= 0.027			

Table 8c : Frequency Distribution of Table 7c

Cell Boundaries	Midpoint	Tally	Frequency
1.295 - 1.315	1.305	*	1
1.315 - 1.335	1.325	********	8
1.335 - 1.355	1.345	*************	13
1.355 - 1.375	1.365	****************	16
1.375 - 1.395	1.385	******	6
1.395 - 1.415	1.405	****	4
1.415 - 1.435	1.425	**	2
			Total =50

Table 9c : Ink Density of 50% dot area of 50 Samples Collected From Press Run II-1

0.45	0.47*	0.46	0.48	0.46	0.49	0.46	0.46	0.46	0.45	0.48
0.46	0.53*	0.49*	0.49*	0.50*	0.57*	0.51*	0.48	0.50*	0.49*	0.47
0.45	0.48	0.45	0.45	0.46	0.47	0.46	0.44	0.44	0.46	0.46
0.46	0.46	0.46	0.46	0.48	0.46	0.46	0.45	0.47	0.48	0.49
0.49	0.52*	0.46	0.50	0.48	0.46	$\bar{X}$ = 0.47	S = 0.024			

"*" indicats defective sheets because of plate catching-up

Table 7_d : Solid Ink Density Data of 50 Samples Collected From Press Run II-2 (FS No Alc ; Normal Ink)

1.32	1.32	1.32	1.31	1.33	1.35	1.33	1.31	1.34	1.31	1.29
1.33	1.33	1.26	1.35	1.32	1.35	1.34	1.32	1.34	1.32	1.31
1.33	1.33	1.33	1.28	1.32	1.32	1.34	1.30	1.33	1.34	1.34
1.32	1.34	1.32	1.34	1.33	1.31	1.34	1.32	1.32	1.32	1.35
1.32	1.32	1.34	1.31	1.34	1.35	$\bar{X}$ = 1.33		S = 0.018		

Table 8_d : Frequency Distribution of Table 7_d

Cell Boundaries	Midpoint	Tally	Frequency
1.255 - 1.275	1.265	*	1
1.275 - 1.295	1.285	**	2
1.295 - 1.315	1.305	*******	7
1.315 - 1.335	1.325	************************	24
1.335 - 1.355	1.345	****************	16
			Total =50

Table 9_d : Ink Density of 50% Dot Area of 50 Samples Collected From Press Run II-2

0.44	0.43	0.43	0.44	0.44	0.45	0.45	0.44	0.46	0.44	0.43
0.43	0.44	0.44	0.45	0.44	0.45	0.46	0.46	0.44	0.44	0.45
0.44	0.44	0.45	0.45	0.45	0.44	0.46	0.44	0.45	0.45	0.45
0.45	0.45	0.45	0.45	0.46	0.45	0.46	0.45	0.45	0.46	0.45
0.45	0.45	0.46	0.46	0.45	0.46	$\bar{X}$ = 0.45		S = 0.009		

Printing Characteristics of the Four Test Experiments

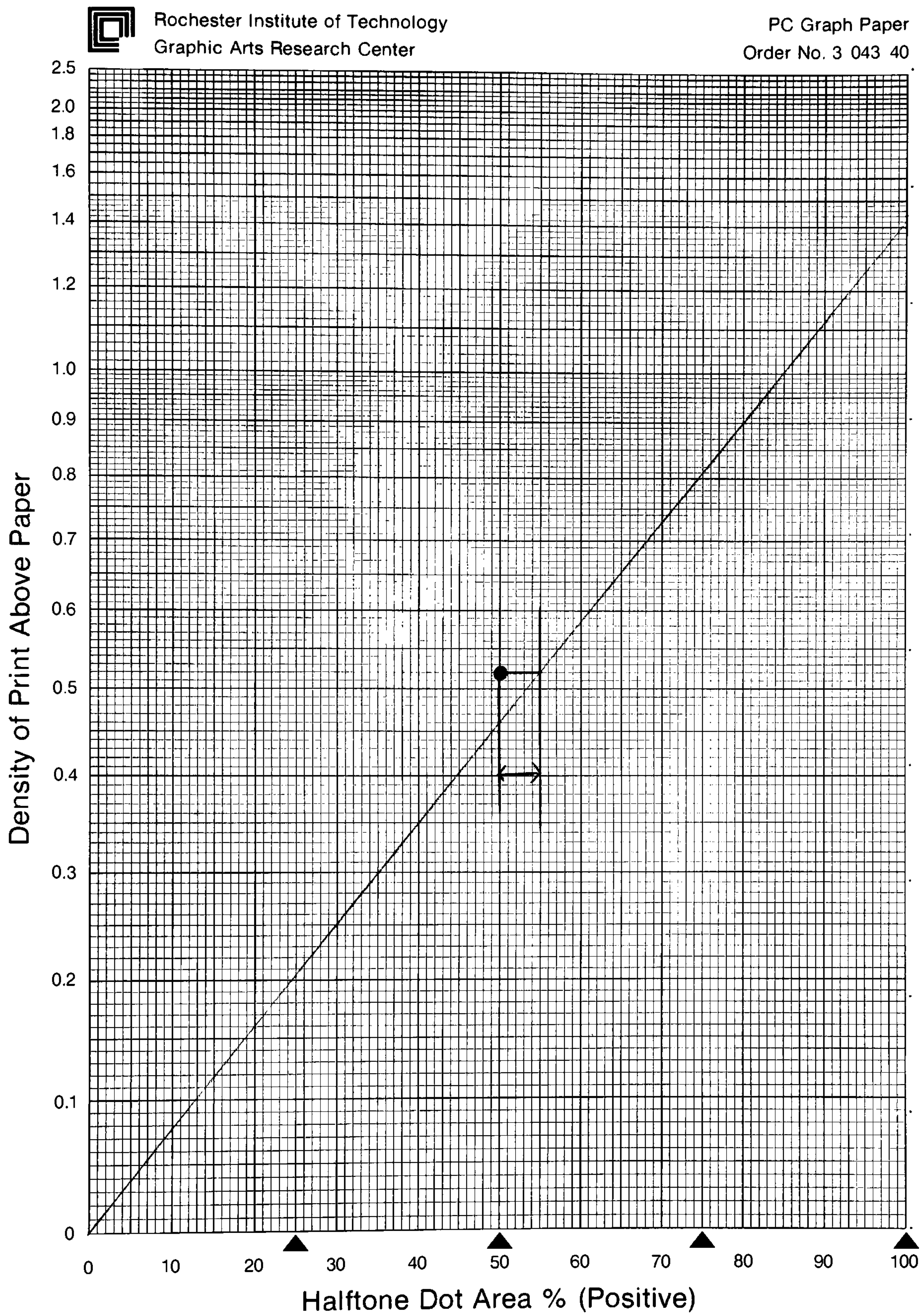
On a subjective visual basis the printed results of the four test experiments are approximately equal. The printing quality of non-alcohol run appears to be sharper, the difference however is subtle.

The printed sheets were furthur studied by application of PC graph paper (PC for printing characteristic) as a shortcut method for the estimation of dot gain. Dot gain calculation based upon Murray-Davis equation and upon Yule-Nielsen equation are listed in Appendix I. With the use of PC graph paper, dot gain of each test combination was obtained by connecting the average solid ink density with the origin. A straight line is drawn between these two points. The straight line is used as reference to indicate the dot gain at 50%. Table 10 lists the average dot gain determined by this method for each test combination. These results show that the dot gain is higher at both printing units when the press is running with alcohol dampening solution.

Table 10 : Average Dot Gain Obtained From Each Test Combination

Fountain Solution	Modified Ink #6-M	Normal Ink #6
FS-235 (alcohol dampening solution)	5.0%	4.5%
FS-0 (non-alcohol dampening solution)	1.7%	0.5%

Figures 16, 17, 18, 19 are graphs indicating the average dot gain of the four test experiments using PC graph paper.

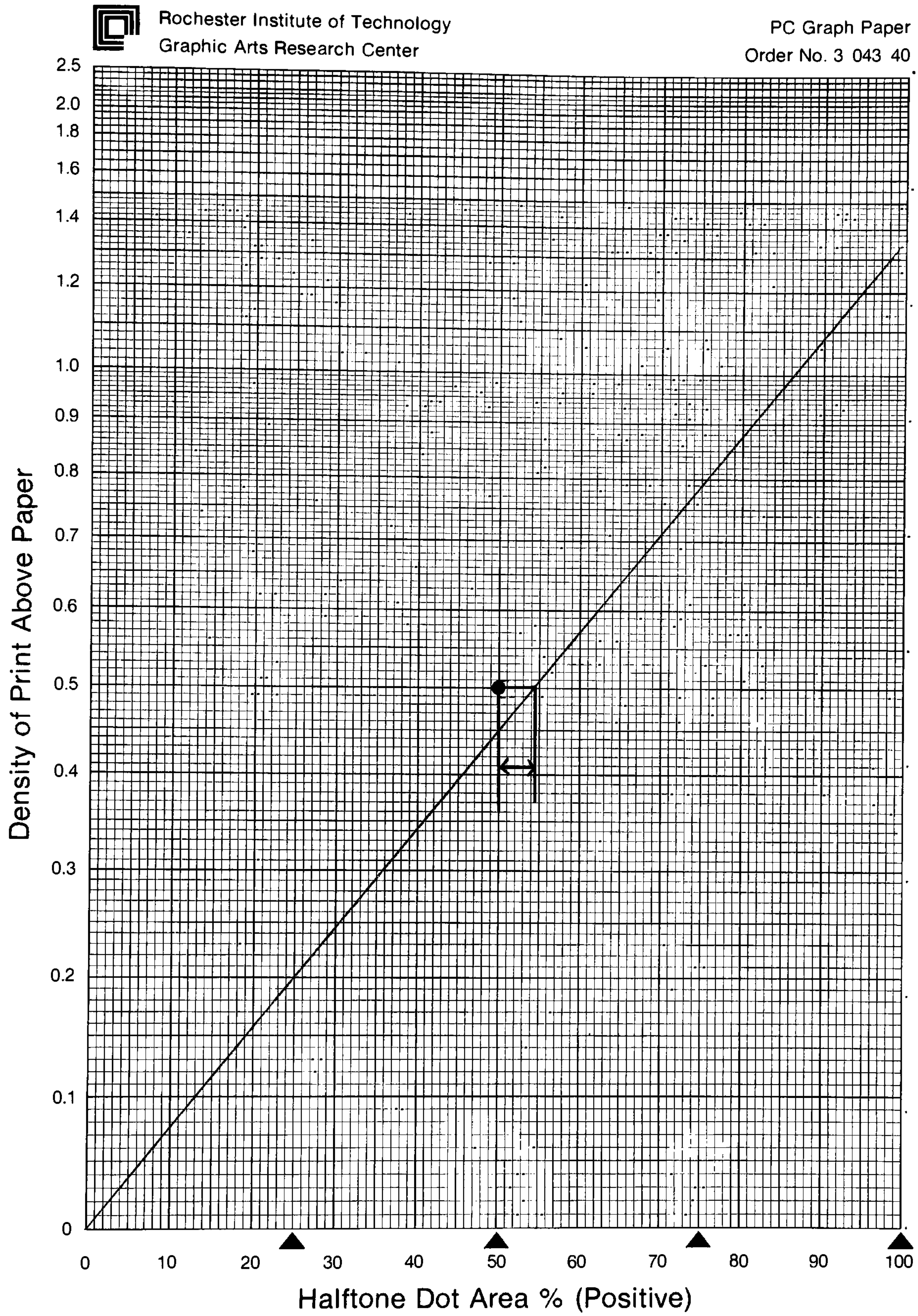


Notes: Figure 16 : Dot Gain of Press Run I-1

Average Solid Ink Density = 1.44

Average Density of 50% Dot Area = 0.52

Average Dot Gain = 5.0%

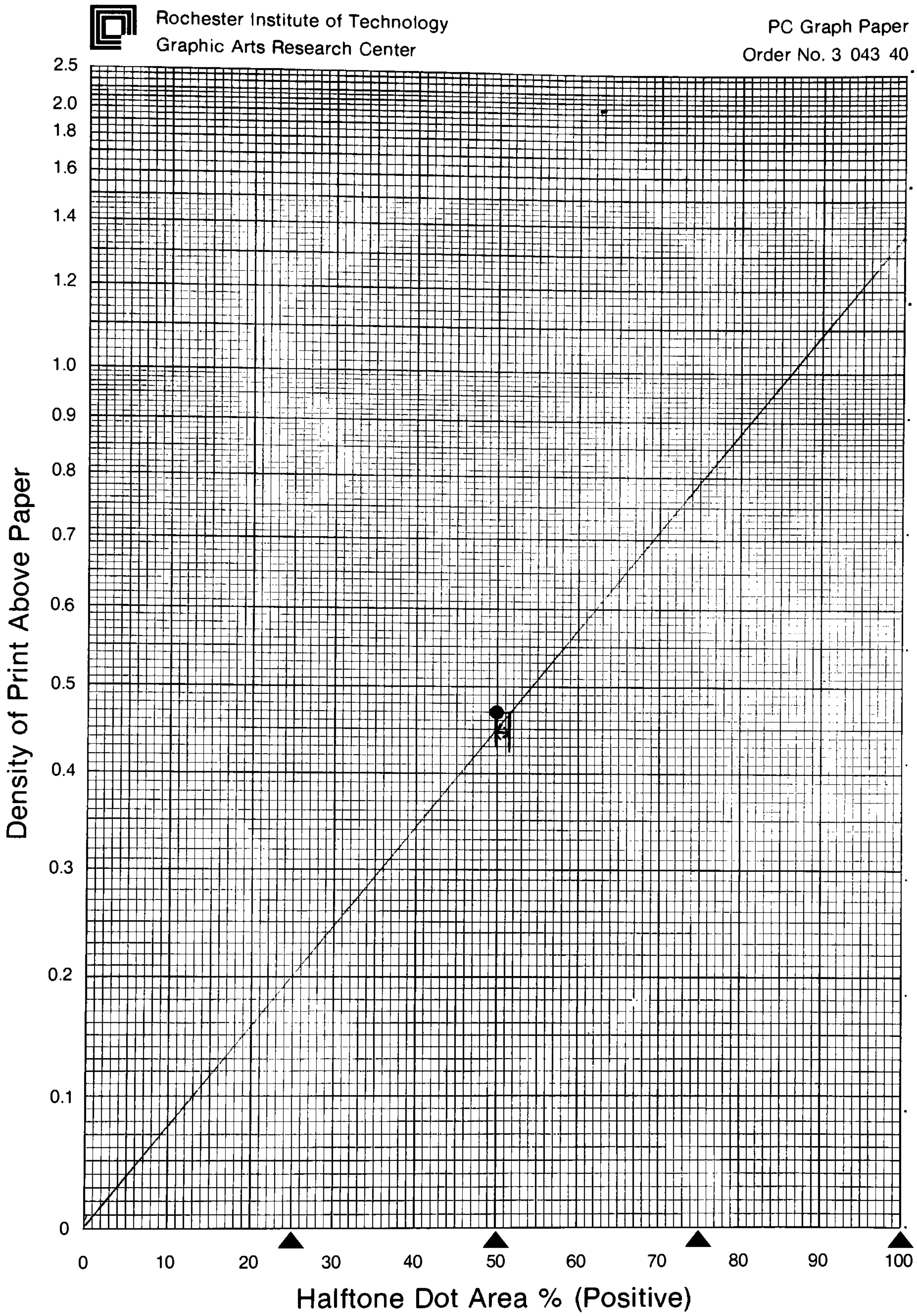


Notes: Figure 17 : Dot Gain of Press Run I-2

Average Solid Ink Density = 1.36

Average Density of 50% Dot Area = 0.50

Average Dot Gain = 4.5%

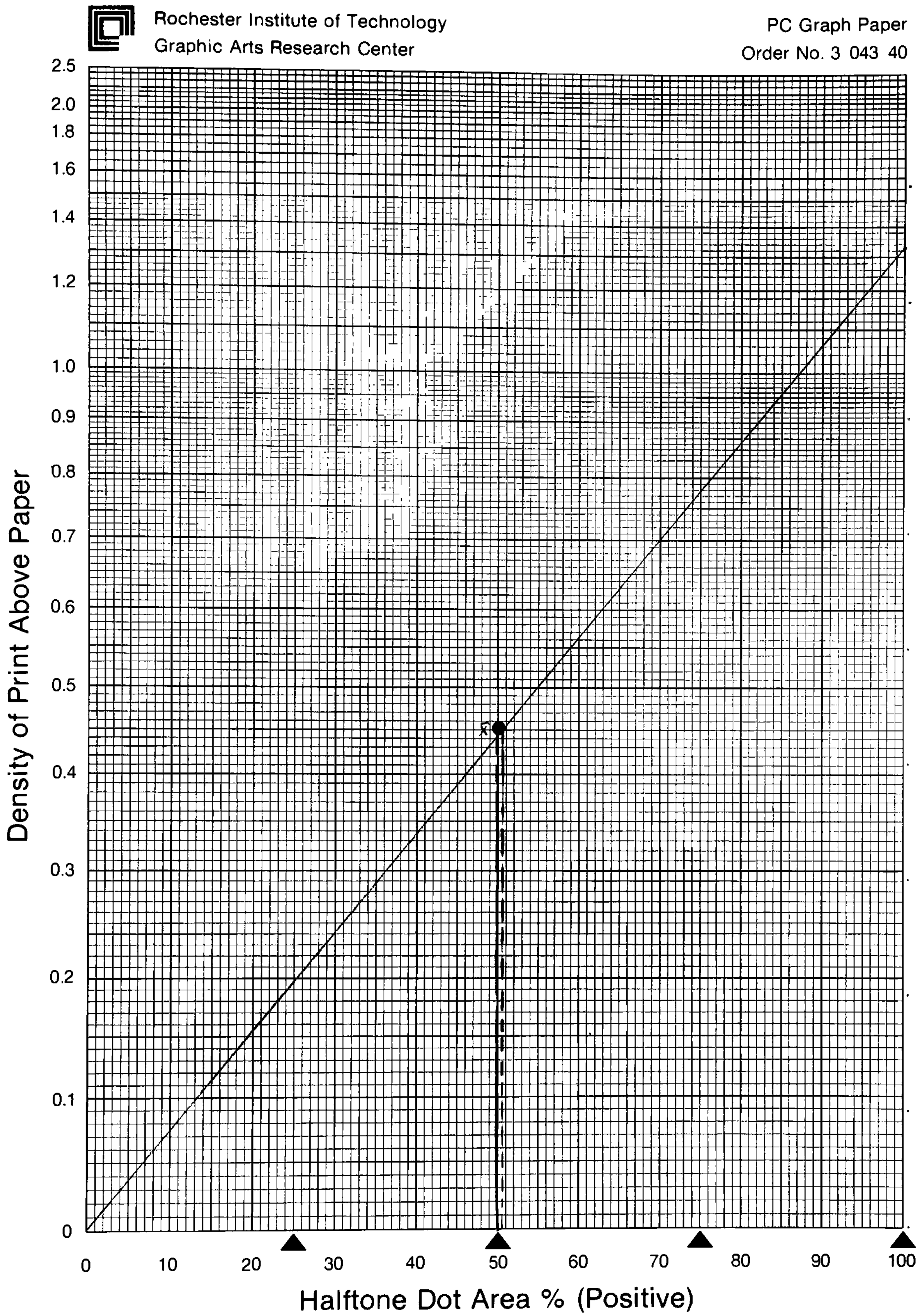


Notes: Figure 18 : Dot Gain of Press Run II-1

Average Solid Ink Density = 1.36

Average Density of 50% Dot Area = 0.47

Average Dot Gain = 1.7%



Notes: Figure 19 : Dot Gain of Press Run II-2

Average Solid Ink Density = 1.33

Average Density of 50% Dot Area = 0.45

Average Dot Gain = 0.5%

Comparison of the Printing Results Which Are Associated With the Four Different Emulsification Rate Curves

The variation of the printing results are compared using solid ink density and dot gain response. The size of variation set at $\pm$ 2 sigma, includes 95% of measurements. This is the usual critical level which is practical in industrial applications.

Table 11 and table 12 are the solid ink density and dot gain averages and variations of the four test runs which are associated with the four different emulsification rate curves.

Table 11 : Average Solid Ink Density and the $\pm$ 2 Sigma Interval

	Modified Ink #6-M	Normal Ink #6
Alcohol Dampening Solution	1.44 $\pm$ 0.050	1.36 $\pm$ 0.040
Non-Alcohol Dampening Solution	1.36 $\pm$ 0.054	1.33 $\pm$ 0.036

Table 12 : Average Dot Gain and the $\pm$ 2 Sigma Interval

	Modified Ink #6-M	Normal Ink #6
Alcohol Dampening Solution	5.0% $\pm$ 2%	4.5% $\pm$ 2%
Non- Alcohol Dampening Solution	1.7% $\pm$ 5.3%	0.5% $\pm$ 1.5%

Test of Hypothesis

Both ink #6-M and ink #6 are classified as good inks when mixed with alcohol dampening solution. The emulsification rate curves are of Pc type according Surland's classification. These two inks form a Pb type of emulsification rate curve when they are mixed with non-alcohol fountain solution. They are therefore classified as non-ideal inks.

Table 11 indicates that the printing runs using the ideal inks do not produce a lower solid ink density variation than the printing using the non-ideal ink. The average solid ink density and the $\pm$ 2 sigma interval in printing run using ink #6 and non-alcohol dampening solution is 1.33 $\pm$ 0.036. Although this is not an ideal ink, it produces a lower solid ink density variation. The size of the solid ink density variation is not predicted by the emulsification rate curves proposed by Aage Surland.

Table 12 shows that the printing run using a non-ideal ink produces the lower amount of dot gain variation. The size of dot gain variation is $\pm$ 1.5% using PC paper graph.

Both table 11 and table 12 indicate that the size of variation in solid ink density and dot gain was not predicted in this experiment by the emulsification curves. An ideal ink defined by Surland does not necessary produce a lower variation in solid ink density or dot gain.

<u>Additional Observations of the Printing Run Using Ink #6-M and Non-Alcohol Dampening Solution</u>

The printing run using ink #6-M and non-alcohol dampening solution were analyzed to determine which treatment had the largest dot gain variation. The printed sheets which were sampled were reviewed and the cause are found.

Ten of the sheets which were sampled are found to be defective due to plate "catching up". The defective sample sheets are marked "*" in table 7c and 9c at page 55. Table 13 and 14 indicate the adjusted results.

Table 13 : Average Solid Ink Density and the $\pm$ 2 Sigma Interval (Modified)

	Modified Ink #6-M	Normal Ink #6
Alcohol Dampening Solution	1.44 $\pm$ 0.050	1.36 $\pm$ 0.040
Non-Alcohol Dampening Solution	1.35 $\pm$ 0.046	1.33 $\pm$ 0.036

Table 14 : Average Dot Gain and the $\pm$ 2 Sigma Interval (Modified)

	Modified Ink #6-M	Normal Ink #6
Alcohol Dampening Solution	5.0% $\pm$ 2.0%	4.5% $\pm$ 2.0%
Non-Alcohol Dampening Solution	1.7% $\pm$ 2.3%	0.5% $\pm$ 1.5%

Table 13 and table 14 are the modifications of table 11 and table 12. The 10 defective sample sheets were removed from the 50 randomly collected samples in the printing run using ink #6-M and non-alcohol fountain solution. The average solid ink density and dot gain were recalculated based upon 40 good printed sheets. The new standard deviation was also recalculated.

Comparison of table 13 with table 11 and table 14 with table 12 indicates that the size of solid ink density variation as well as dot gain variation is reduced. The printing run using ink #6-M and non-alcohol produces increased variation due to the effect of plate "catching up". Plate "catching up" is defined as the situation where the non-image areas of the plate is taking ink. It can be reversed by increasing dampening feed.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This thesis confirms that each combination of ink and fountain solution forms a characteristic ink emulsification rate curve as a result of using a modified, Surland technique. The experimental results show that the emulsification rate curve is subject to change due to the changes in the ink formula or due to a difference in fountain solution surface tension.

The addition of isopropyl alcohol to the fountain solution reduced the surface tension of the dampening solution. The presence of isopropyl alcohol in a dampening solution aids the ink to reach a state of equilibruim with the fountain solution. Conversely it suppresses on ink's continuous emulsification tendency with the dampening solution. Figure 12 indicates the effect of isopropyl alcohol in eight selected sheet-fed offset inks. All the test inks have a continuous emulsification tendency with non-alcohol dampening solution, that is the emulsification rate curves do not flatten out at the tail end of the curves. With the use of alcohol dampening solution, all the curves are reduced in their emulsification capacity. Some of the inks tested reach the state of equilibruim with alcohol dampening solution.

A proposed inkometer method was attempted for correlation with Surland's method. The conclusion is that with the proposed inkometer method the dynamic change of ink's miscibility with fountain solution is not measureable. Due to the limits in the use of inkometer, a correlation of these two methods can not be established.

Ink #6-M was ink #6 successfully modified by the addition of 10% glycerol producing an ink with a tack equal to onk #6. Using Surland's technique ink #6-M deteriorates by with a steeper emulsification rate curve shown by figure 15 in non-alcohol fountain solution. Ink #6-M remains classified as a good ink with the alcohol fountain solution. On the basis of observation of the simulated printing production run, the printing performance of the four emulsification rate curves support Surland's performance rating. The pressman was required to make three adjustments to dampener feed at printing unit 1 and two adjustments in dampener feed at printing unit 2 when he was running the job using non-alcohol dampening solution. The adjustments were made to overcome plate catching-up. This is a prediction based on the Surland's curves.

Analysis of solid ink density data collected from the four test combinations appears to indicate that solid ink density variation within a printing run is independent of an ink's emulsification rate curve. Printing with inks of different emulsification rate curves do not correspond with a major change in the size of solid ink density variation. Printing using a non-ideal ink on the contrary exhibits the lowest relative variation.

Analysis of dot gain data collected from the four test combinations indicates that the printing using alcohol dampening system produces more dot gain than the printing with a non-alcohol dampening system. The average dot gain obtained from printing press run II-2 is 0.5% using ink #6 and non-alcohol dampening solution. Printing using an alcohol dampening solution has about 5% of average dot gain at both of the printing units.

Although the average dot gain is 5% with an alcohol dampening system, the dot gain variation within a printing run remains relatively constant. Printing press run II-1 has the average dot gain of 1.7% but the size of dot gain variation is the largest. Due to the difficulty in maintaining scum free prints the dot gain variation becomes the greatest.

The cause of plate "catching up" is confirmed by this simulated production printing run. In addition to a possibility of improper ink feed or water feed set up by a pressman, the tendency of plate "catching up" is associated with emulsification rate curves. The Pb type of emulsification rate curves can be modified such that press run will encounter fewer problems during a printing run, density variations within a press run then is controlled.

The study of the effect of alcohol on the dissolution of the toner in the ink and its relationship with ink film thickness is recommended for furthur study.

APPENDIX I

Conversions of dot gain results using both Yule-Nielsen and Murray-Davis equations.

Murray-Davis

Formula: $$\% D = \frac{1-10^{-(Dt/n)}}{1-10^{-(Ds/n)}}$$

$n = 1.0$

% D = % Dot Area
Dt = Density of the Tint
Ds = Density of the Solid

Yule-Nielsen

Formula: $$\% D = \frac{1-10^{-(Dt/n)}}{1-10^{-(Ds/n)}}$$

$n = 1.7$

% D = % Dot Area
Dt = Density of the Tint
Ds = Density of the Solid

The following table shows dot gain averages and variations of the four test runs which are associated with the four different emulsification rate curves. Dot gain calculation using PC graph paper, Murray-Davis equation and Yule-Nielsen equation are compared.

Fountain Solution	Modified Ink #6-M			Normal Ink #6		
	PC Graph	Murray-Davis	Yule-Nielsen	PC Graph	Murray-Davis	Yule-Nielsen
Alcohol Dampening Solution	5.0% ± 2.0%	22.4% ± 1.9%	8.9% ± 2.0%	4.5% ± 2.0%	21.5% ± 2.4%	8.5% ± 2.0%
Non-Alcohol Dampening Solution	1.7% ± 5.3%	19.1% ± 4.1%	6.0% ± 4.3%	0.5% ± 1.5%	17.7% ± 1.6%	4.7 % ± 1.8%